DOCUMENT RESUME

ED 074 527 24 CS 200 523

AUTHOR	Frederiksen, Carl H.
TITLE	Cognitive Aspects of Learning in Arbitrary and Non-Arbitrary Contexts: Acquisition of Knowledge from Natural-Language Discourse. Final Report.
INSTITUTION	California Univ., Berkeley. Dept. of Psychology.; California Univ., Berkeley. Inst. of Human Learning.
SPONS AGENCY	National Center for Educational Research and Development (DHEW/OE), Washington, D.C. Div. of Comprehensive and Vocational Education Research.
BUREAU NO	BR-9-0396
PUB DATE	Feb 73
GRANT	OEG-0-9-140396-4497(010)
NOTE	329p.
EDRS PRICE	MF-$0.65 HC-$13.16
DESCRIPTORS	*Comprehension Development; *Discourse Analysis; *English; Language Research; Learning; Linguistic Competence; *Linguistics; Recall (Psychological); *Semantics

ABSTRACT

This research studied the processes which enable people to acquire semantic information from natural-language discourse. Specific objectives were: (1) to represent semantically the structural meaning of English discourse by a well-defined semantic model; (2) to develop a way of using the semantic representation of a text as a structural model for scoring a subject's acquired knowledge; (3) to develop a process model for discourse comprehension; and (4) to investigate hypotheses about the effects of certain contextual conditions, designed to induce inferences about text content, on knowledge acquired from a text. Written reconstructions of knowledge acquired from a text were used in three experimental contexts: "arbitrary," "problem solving," and an incidental memory condition. Basic data consisted of the relative frequencies of classes of response from a semantic analysis of recall procedures. Results were consistent with a model of comprehension consisting primarily of "generative" rather than purely "interpretive" processes. Sources of individual differences were also studied. Part 2 contains a detailed development of a semantic structural model of English discourse and a technique for measuring semantic information acquired from discourse. (Author/DI)

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Final Report

Project No. 9-0396
Grant No. OEG-0-9-140396-4497(010)

COGNITIVE ASPECTS OF LEARNING IN ARBITRARY AND NON-ARBITRARY CONTEXTS

Acquisition of Knowledge from Natural-Language Discourse

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February, 1973

The research reported herein was performed pursuant to a grant with the Office of Education, U. S. Department of Health, Education, and Welfare. Contractors undertaking such projects under Government sponsorship are encouraged to express freely their professional judgment in the conduct of the project. Points of view or opinions stated do not, therefore, necessarily represent official Office of Education position or policy.

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Office of Education
National Center for Educational Research and Development

CS200 523

Abstract

This research was concerned with the processes which enable individuals to acquire semantic information from natural-language discourse. Specific objectives were: (1) to represent semantically the structual meaning of English discourse in terms of a well-defined semantic model, (2) to develop a procedure for using the semantic representation of a text as a structural model against which a subject's acquired knowledge can be scored, (3) to develop a process model for discourse comprehension, and (4) to investigate hypotheses concerning effects of certain contextual conditions designed to induce inferential operations on text content on knowledge structures acquired from a text. The task involved obtaining repeated written reconstructions of knowledge acquired from a text. Three experimental contexts were used: (1) an "arbitrary" context, (2) a "problem solving" context, and (3) an incidental memory condition (three problem solving trials followed by incidental recall). Groups one and two wrote four recalls; all groups were tested one week later. Basic data consisted of the relative frequencies of classes of response obtained from a semantic analysis of recall protocols. Results were consistent with a model of comprehension consisting primarily of "generative" rather than purely "interpretive" processes. Sources of individual differences were also studied. Part II contains a detailed development of a semantic structural model of English discourse and an associated technique for measuring semantic information acquired from discourse.

PREFACE

The research to be described in this paper began as a project concerned with investigating cognitive processes involved in "complex ideational learning", i.e. in acquiring new semantic information from natural language discourse. One reason for undertaking such a study was the lack of research employing natural-language discourse in non-verbatim learning tasks and our consequent ignorance about the processes involved in such learning. A second was that rote learning tasks themselves appear to involve organizational processes which are rather more specific to a given task than has generally been supposed (Frederiksen, 1969, 1970). Thus it was decided to investigate processes governing the acquisition of non-verbatim knowledge in different learning contexts to attempt to gain some understanding of these processes and the extent of their invariance over different contexts in which this learning takes place. In particular, two sorts of contexts were to be considered: an arbitrary context in which a set of linguistically coded semantic elements are to be acquired, remembered, and reconstructed; and a non-arbitrary context in which, in addition to being remembered and reconstructed, these elements are to be the object of some additional stipulated cognitive operations such as applying inductive or deductive reasoning to solve a problem involving the elements, or relating a set of ideas to other knowledge in a nonarbitrary manner. It was supposed that processes involved in acquiring knowledge from connected, logical arguments might be dependent on the nature of "superordinate" processing operations on the semantic content of the essay. Thus, the experimental strategy adopted involved manipulating through task conditions the likelihood and extent to which individuals would adopt certain modes of information processing which involve cognitive operations on the semantic content of a connected verbal argument and studying various properties of the temporal course of learning performance for different task-groups so defined.

Naturally, the first problem encountered in this work (and the key problem confronting anyone attempting to study in a direct manner the acquisition of nonverbatim knowledge from discourse) was that of obtaining a sufficiently objective and complete specification of the semantic properties of the stimulus passage and obtaining a set of measurements which are sufficient to provide an objective and sufficiently complete description of the properties of the verbal protocols which constitute "learning performance." A starting point for the development of a solution to this problem of formally specifying the semantic properties of a stimulus passage consisting of a connected logical discourse was suggested by Dawes' (1966) experiments on the distortion of meaningful written materials in remembering, and Frase's (1969) demonstrations of the effects of thinking about particular semantic relations present in a text (represented structurally in the form of directed graphs) on recall of elements taken from the text.

Dawes developed passages around a number of set relations and attempted to measure by reference to the set relations specified in the passage processes of distortion of relationships and selection in memory. Frase's work incorporated the idea that textual materials may be represented in terms of networks of set relations symbolized as directed graphs (cf., Harary, Norman, and Cartwright, 1965).

Having decided to try to represent the semantic features of a connected discourse as a network of set relations, it was decided that a set of conventions would have to be developed for the specification of a semantic model for any connected passage. The model was to be represented diagrammatically or, more rigorously, as graph-structures of two sorts: (1) a semantic structure graph representing relations among concepts and (2) a logical structure graph representing implications among propositions. Incidentally, it was initially felt that it is not necessary that such a model be unique, only that it be well defined and capable of generating the passage. The problem of scoring semantic or "ideational" features of a subject's written reconstruction of the input could then be treated by reference to the model of the input by a templating-matching process, provided that a satisfactory model is available. At this point another difficulty was encountered. Given a structural model of the input and a subject's written reconstruction of the input (presumably also representable structurally using the same conventions used to develop a structural model of the input), how might the degree of correspondence of these two structures be measured? For example, if a particular relation ARB is present in the input (where R is a directed relation from concept A to concept B) and a relation A'R'B' is present in a subject's written protocol, how might A'R'B' be identified with a relation ARB contained in the model of the input, and given such identification, how might the subject's relation differ from the relation of the model with which it is identified? In the presence of these complexities, it appeared that the development of a solution to the scoring problem just described would require the statement of some sort of outline of a theory of comprehension as well as of memory processes. Since the verbal protocol produced by a subject as a reconstruction of a connected logical argument which he has just read or heard is the result of a sequence of comprehension-memory-reconstruction processes, relations between ARB and A'R'B' ought to be describable in terms of classes of responses resulting from the application of these processes.

The research activities described in this report reflect these developments in our conceptualization of the problem and hence the scope of the activities reported here goes considerably beyond that of the originally proposed study. As a result, the work has become more heavily oriented towards psycholinguistic questions and information processing models. Our initial activities described in Part I involved developing the outlines of a model for semantically representing English texts, a procedure for measuring semantic knowledge acquired from texts, and the outlines of a process model. Our later activities described in Part II have been concerned predominantly with the problem of developing a formal semantic model for representing any natural language discourse up to a paraphrase transformation, and with developing a satisfactory procedure for representing the semantic information which results when subjects reconstruct the knowledge which they have acquired from a presented discourse.

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Problem and Objectives

Stated in general terms, the long-term objectives of the research reported here are to identify and measure processes by which individuals are able to acquire semantic knowledge from English discourse, to determine the extent of invariance of these processes, and to identify sources of individual differences in these processes. A more specific statement of these objectives requires both a satisfactory definition of what "semantic knowledge" consists of and how it may be represented and measured, and a satisfactory definition of processes which may be involved in acquiring semantic knowledge from a discourse. While there are considerable bodies of research, both linguistic and psychological, which are pertinent to these problems, there is virtually nothing existing in the literature which provides either a ready-made procedure for representing English texts semantically or a satisfactory account of possible alternative processes or process models for the comprehension and memory of information presented in texts. Thus, a very considerable amount of effort in this project has been devoted to these problems. Once a well-defined procedure is available for representing an English text semantically, the resulting semantic representation of a text (semantic model) can be used as a reference structure (or "template") against which a subject's acquired semantic knowledge may be measured. Then, given the semantic model and the measurement procedure, it becomes possible to investigate particular processes involved in acquiring knowledge from a presented discourse by identifying properties of discourses and discourse contexts which effect outputs associated with particular processing operations in comprehension and semantic memory.

The basic data resulting from the above semantic analysis consist of the relative frequencies of particular classes of semantic structural elements which have been defined in the semantic model and which are observed in subjects' verbal reconstructions of the knowledge they have acquired from a text. Observed semantic elements in a subject's verbal protocol may be reproduced (i.e. they may correspond to elements of the semantic model), or they may be transformed or generated by the subject himself. Individual and group differences may be described in terms of the relative frequency of occurrence of particular classes of semantic elements and in terms of the extent of employment and efficiency of particular processes in comprehension and semantic memory. The emphasis in the present research is on the comprehension (acquisition) of semantic knowledge and on cognitive operations on knowledge structures only insofar as they relate to processes of acquisition.

Specific objectives include: (1) the development of a formal method for semantically representing the structural meaning of English discourse, (2) the development of a method for measuring correspondences between the "meanings" of a discourse and the "meanings" conveyed by a subject in reconstructing the knowledge he has acquired from a presented discourse given a well-defined logico-semantic representation of the input passage but only the surface structure of a subject's reconstruction, and (3) the investigation of process-invariance re. possible effects of context-induced cognitive operations on semantic information acquired from a discourse on the processes used to acquire that information.

The first sections of this chapter briefly review research pertinent to the following four problems: (1) representing semantically the information content of English prose passages in terms of a well-defined semantic and logical structural model, (2) developing a procedure for using the semantic representation of a text as a structural model against which a subject's acquired knowledge may be analysed and scored, (3) developing a reasonably well-defined process model for language comprehension and semantic memory, and (4) investigating hypotheses concerning the effects of surface and semantic properties of discourses and discourse contexts on knowledge structures acquired in comprehending and remembering semantic information presented in linguistically encoded form. Procedures for representing the semantic structure of a text and for measuring semantic knowledge acquired from a text which have been developed in the present research are described briefly to indicate their relationship to prior techniques. Research concerned principally with effects of discourse contexts will be reviewed in chapter 2.

1.2 Semantic Representation of Discourse

An essential precondition for successful research in the area of language comprehension and semantic information processing is to have at hand a technique for specifying in an objective, well-defined manner, the semantic properties of any stimulus passage. Thus, one is confronted at the outset with the difficult problem of developing a semantic description of English texts which is capable of representing discourses consisting of many sentences, given only the surface structure of the text. A general requirement of such a semantic description of a text is that it should not represent the surface grammatical structure of the text (except insofar as the surface structure uniquely represents a given meaning); rather, a semantic description should be capable of representing each sentence only up to a paraphrase transformation. Thus, from a given semantic structure one should in general be able to generate a set of grammatically well-formed sentences, each of which expresses the meaning specified by the semantic structure. This requirement stems from the premise that a minimal demonstration of comprehension of a text consists of the ability to paraphrase the text.

A semantic representation of natural language sentences has been considered by many linguists to consist of a set of lexical elements (represented semantically as, e.g., a set of binary features) which are interrelated in networks of structural relations, both in the surface sentences (surface grammatical structure) and in the underlying propositions from which the surface sentences (and their paraphrases) are derived ("deep" semantic structure). Linguistic theories differ in the extent to which they are willing to define "deep structure" relations which are distinct from syntactic relations (which are defined in the surface structure or "syntactic deep structure"). Recent work in "generative semantics" (e.g. Maclay, 1972; Lakoff, 1972) and the case grammar ideas of Fillmore (1968, 1971) provide the starting point for a structural semantic description of discourse which is not defined solely in terms of grammatical relations appearing in the surface sentences. These approaches to semantic description recall the stratificational approach of structural linguistics which supposes that sentences can be described in terms of a number of self-contained descriptive levels (e.g. phonological, syntactic, semantic) with rules of expression which map from "deeper" levels to more surface levels (e.g. from semantic deep structure to surface sentences, or from surface sentences to sound patterns) (cf. Leech, 1969). From this point of view, a syntactic description should not be developed in isolation, but should provide an optimal input to the semantic system (cf. Halliday, 1967, 1970). The present discussion will be concerned exclusively with the problem of developing a self-contained semantic representation of English discourse. To make this restricted problem more manageable, it seems possible to adopt the limited objective of representing only the structural as opposed to lexical meaning of a text. Thus, rather than attempt to represent concepts corresponding to lexical elements structurally, concepts will be taken as "primitives" in the semantic analysis and will be represented by lexical designators which are referred (at present) to standard dictionary citations. This limited objective has been adopted here to avoid the problem of determining how much lexical analysis to include (i.e. how much to "deconflate" lexical elements), and to expedite scoring subjects' reconstructions of the meaning of a text. It is not yet clear whether or not individual lexical elements should be considered to be "primary" functional units in semantic long-term memory.

Two procedures for representing a discourse semantically were developed in the present research and are described in detail in chapters 3 and 9. The first procedure which was developed was intended to represent structurally the "essential" logical features of a passage in a manner similar to précis-writing so that the resulting semantic structure (a network or graph consisting of nodes and connecting relations) could be used as a model or template against which one could score subjects' written reconstructions of the knowledge they had acquired from the passage. This procedure provides a relatively global summary of certain logical and semantic properties of a passage. In order to have a more detailed and linguistically-based semantic structural model of English discourse which is capable of representing more complex texts and semantic relations, and yet one which continues to represent the inter-clausal "logical" structure as well as the intra-clausal "semantic" structure, a second procedure was developed for representing the logico-semantic structure of discourse. The second procedure was influenced substantially by recent work in linguistic semantics (Fillmore, 1968, 1971), computational linguistics (Simmons, 1968, 1970, 1971, 1972), artificial intelligence (Quillian, 1968; Raphael, 1968; Winograd, 1972; Schank, 1971), and psycholinguistic work involving discourse (Crothers, 1970, 1971). Well-known concepts from logic and algebra were employed as well as Rescher's (1964) analysis of contrafactual conditional statements and Simon and Rescher's (1966) analysis of causal contrafactuals. Other relevant work includes the work of Lakoff (1972) and Chafe (1970) in linguistic semantics, the work of Kintsch (1972) and Rummelhart, Lindsey and Norman (1972) in semantic memory, and recent work in developmental psycholinguistics concerned with semantic description of pre-school children's speech (Antinucci, 1970, 1971; Wells, 1972; Wells, Antinuuci, and Slobin, 1972).

The second procedure (described in detail in Chapter 9) differs from the earlier one in a number of important respects. First, it represents a text as two separate graphs consisting of nodes connected by directed lines representing binary relations (cf. Harary, Norman, and Cartwright, 1965): a semantic structure graph representing binary semantic relations defined on concept-pairs such as relations of attribution, possession, quantification, and case relations involving active or stative verbs (cf. Fillmore, 1971); and a logical structure graph representing various logical (intersential) connectives defined on propositions which are represented in the semantic structure graph. This representation of a text as two separate graphs appears to be desirable for a number of reasons (which are indicated in Chapter 9). Second, the concepts (which are the "givens" or "primitives" in the analysis) correspond to single lexical items. No attempt is made in the present analysis to represent the lexical primitives semantically nor is any position taken on the nature of such representations. Rather, the purpose is to attempt to represent those semantic structural relations which a given discourse imposes (explicitly or implicitly) on its lexical elements. Third, since the two graph structures are in themselves insufficient to represent a text structurally, seven basic operators on relations in the semantic or logical structure graphs are defined which qualify or constrain the truth value of the relation to which they are applied. These operators include a truth-value operator (negation), probability operator (e.g. qualifying modal auxiliaries), temporal operator (tense), aspect operator, node deletion operator (e.g. deletion of a concept having an implied case-relation to a verb), conditional operator (which renders a relation conditional on other semantic relations) and interrogative operator (which interrogates the probability attached to a relation). Both logico-semantic structural models are capable of representing structural properties of discourses consisting of many sentences. From the point of view of semantic analysis, sentence or clausal boundaries are regarded as surface phenomena having no intrinsic semantic interest. The result of these changes is a structural representation of prose which resembles in certain respects that of Simmons (1968, 1971, 1972) and utilizes principles of semantic analysis similar to those recently discussed by linguists (cf. Fillmore, 1968, 1971; Leech, 1970), psycholinguists (cf. Clark, 1972), and researchers interested in computer models of language processors (e.g., Quillian, 1968; Raphael, 1968; Schank, 1971; Winograd, 1972).

Despite the limited number of defined semantic and logical relations, this structural model appears to be capable of representing some rather complicated semantic relations (e.g. relative degree,time, location; modal expressions such as "may", "must", etc.). Its ability to represent relatively complicated texts is also demonstrated by the analysis of the essay on school desegregation presented in Chapter 9. Note that while it is convenient (for scoring purposes) to represent a text in the form of a directed graph, a graph structure may be alternatively represented as a list structure (using a programming language such as LISP or SNOBAL). In the future we plan to use such list representations. The idea would be to store a semantic structure corresponding to a stimulus text in the form of a list-structure, input to the computer a semantic structure corresponding to a subject's verbal protocol, and program the computer to evaluate the "match" between the two structures. List structure representations have been employed in most work in computational linguistics (Simmons, 1971) and semantic information processing programs (Quillian, 1968; Raphael, 1968; Winograd, 1972).

1.3 Measurement of Comprehension

Once a method is available for representing a text in terms of a well-defined logico-semantic model, in principle the same method that is used to analyze a text which is input to a subject can also be used to analyze a subject's verbal reconstruction of the knowledge he has acquired from the input text. In practice, the task of semantically analyzing a discourse is sufficiently complex that it is extremely unlikely that if such a procedure were employed without modification to measure comprehension, it could be made sufficiently reliable (replicable), especially if the semantic analysis of a subject's protocol is to be made in a reasonably short time. If the "meaning reconstruction" task is used to assess comprehension, the problem of measuring comprehension amounts to that of measuring or evaluating the extent to which the "meaning" of the input text has been preserved or altered in the subject's verbal reconstruction, i.e. given the semantic model of the input, the problem is to obtain objective and replicable measurements of the correspondences between structural elements present in the model of the input and semantic structural elements present in the subject's protocol in linguistically encoded from. The scoring methods which have been developed in this research attempt to make the structural analysis of subjects' protocols objective by using the input structure as a model or "template" against which a subject's protocol is fit. These scoring methods are described in Chapters 3 and 10.

Before presenting a brief overview of the method which was developed for measuring logico-semantic knowledge acquired by a subject in comprehending a discourse, other methods which have been employed to "measure comprehension" ought to be considered and compared to "meaning reconstruction" (free recall) as to potential value to research on comprehension. The most important criteria in evaluating a method's usefulness for theory (process)-oriented research are (in addition to criteria such as reliability and feasibility): (1) the method should provide a relatively complete semantic representation of knowledge acquired from a presented discourse; (2) the task should not alter the discourse or the conditions under which the discourse is received in such a way as to make the task unrepresentative of natural conditions of exposure to discourse, (3) the task should permit wide latitude for systematic manipulation of surface and semantic properties of discourses and of discourse contexts, and (4) the task should provide maximum information relevant to identifying and measuring processes in comprehension and semantic memory.

Carroll (1971a, b) has reviewed methods which have been employed to measure comprehension and has classified the methods in terms of particular measurements obtained, temporal conditions of testing, and task characteristics. Of the particular measurements obtained, the most promising appear to be (1) measurements involving the observation of a particular response and the evaluation of the response against some criterion, and (2) time measurements such as measurements of latencies of particular responses or processing times. Latency measurements have been used increasingly in psycholinguistic work concerned with processes in comprehension (e.g. Clark, 1969, 1970; Trabasso, 1971; Olson, 1971; Kintsch, 1972a, b), the method involving predicting the processing time for different tasks based on assumed additivity of processing times associated with particular stages of information processing. A similar rationale seems reasonable for data consisting of relative frequencies of particular classes of response in free recall tasks (frequencies relative to the absolute frequencies of occurrence of the corresponding semantic elements in the input text): a type of response which requires more extensive processing (or which requires certain kinds of processing) might occur with smaller relative frequency than one which requires less extensive processing (or does not require those kinds of processing). Since specific processing operations required in comprehending and remembering a semantic element from an input text ought to be influenced by such factors as the surface, syntactic, and semantic structural properties of the discourse in which the element is embedded, and the "size" and complexity of the element processed, the relative frequencies of occurrence of corresponding reproduced or transformed elements in subjects' free recalls corresponding to these processes ought to be systematically affected by these factors. This rationale has been applied in the present research. On the basis of the four criteria listed above, the relative frequency measurements appear to be preferable to latency measurements as measures of comprehension. In addition, relative frequency measures (or observations of the occurrence or non-occurrence of specific elements in free recalls) have better statistical and psychometric properties than latency measures. For example, in addition to mean relative frequencies of occurrence, one can investigate the degree of statistical dependence of frequency measures, and the degree of statistical dependence of frequency measures on measured subject characteristics, sources of data which can be extremely informative about cognitive processes in comprehension. Techniques for fitting mathematical models to such data to test hypotheses concerning processes in comprehension will be discussed in Chapter 6; correlations of frequency measures with measures of subjects' cognitive abilities will be discussed in Chapter 7.

The temporal conditions of testing identified by Carroll (1971) are (1) responses are elicited or observed during the temporal interval within which a discourse is presented, and (2) responses are elicited or observed following the presentation of the discourse. On the basis of criterion (2), it appears preferable to obtain measurements after the presentation has been completed. The principal reason for making observations during the presentation have been to attempt to measure "pure" comprehension unaffected by memory processes and other processing of information which has been acquired during the presentation interval (such as inference). As will be argued in the next section, it is inadvisable to assume in advance that memory and inferential processes are separable from "comprehension" processes and then adopt a method of observation which renders adequate investigation of the role of memory and inferential processes in comprehension impossible.

Tasks used to measure comprehension may be classified into (A) those which do not alter the "base" comprehension task (uninterrupted presentation of a discourse), and (B) those which do alter this task. Tasks which do not alter the base comprehension task may be further classified into: (1) verification tasks in which verification can be based either on (a) identity of information acquired from a text with information contained in another verbal message, in non-verbal referents (e.g. pictures), or against a subject's prior semantic knowledge; or on (b) analysis of information acquired from a text to produce a match to some referent; (2) reconstruction tasks (free recall): including tasks involving nonverbal reconstruction (e.g. motor, symbolic) and those involving verbal reconstruction; and (3) probe retrieval tasks: including reconstruction of a part of a test associated with a given cue, question answering (involving reconstruction or analytic operations on semantic information contained in a previously presented text), and recognition. The verbal reconstruction task may be verbatim, it may involve paraphrase ("free recall"), and it may involve translation (into another language or symbolism). Tasks which alter the base comprehension task may involve unstructured deletions from the text (e.g. Cloze procedure) or structured deletions (e.g. sentence completion) where deletions may be based on surface or syntactic properties, or on semantic properties.

In selecting a task to "measure comprehension" from among the tasks just classified, it is important to realize that the tasks identified above are not as distinct as they may at first appear. In fact a number of these tasks can be considered to be special cases of a base comprehension task which requires a subject to reconstruct that knowledge which he has acquired from one or more presented texts (where a text may contain structured deletions). It is also important to realize that, from a semantic point of view, every discourse is to some degree semantically incomplete (i.e. contains semantic deletions) in the sense that the semantic structure is incompletely encoded in the surface sentences which make up the text. Examples illustrating this latter point are provided by linguistic work concerned with focus and presupposition (e.g. Fillmore and Langendon, 1971; Chafe, 1970; Lakoff, 1972) and by semantic analyses of discourse such as that presented in Chapter 9. Our observation in this research that after one exposure to a discourse, subjects' reconstructions of knowledge acquired from the discourse often contain about as many inferentially generated semantic relations as reproduced relations (i.e. relations paraphrased from the input text) provides some empirical support for the notion that inexplicit (but inferable) semantic structures are salient properties of a text.

The four criteria listed above argue for adopting the most general task -- the base comprehension task -- and developing a scoring procedure for that task which is capable of representing a subject's verbal reconstruction semantically against a semantic model of the input text. Once such a procedure has been developed for the base comprehension task, it may be applied to variations of that task such as probe retrieval, verification, and structured deletions. Since structured deletions, especially semantic deletions, are only one type of semantic structural property, the structured deletion task represents one kind of semantic structural property whose effect on processes in comprehension and semantic memory can be studied. Probe retrieval and verification tasks in which subjects are presented with stimulus information after presentation of a text, require comprehension of the probe or to-be-verified message. These stimuli may be represented semantically whether or not they are linguistic, and the semantic structure associated with a probe question, cue, or to-be-verified message may be represented as a part of the semantic model of the input text. Thus, for example, a question may be represented semantically as an appropriate interrogation of an element of the input (see Chapter 9) or, if the question involves inference from the input, the required inferences can be represented semantically and interrogated. Thus verification and probe retrieval tasks involve the presentation of multiple texts which may be represented in terms of a single semantic structural model. The presentation of multiple texts is an important experimental technique (and will be used in the first experiment proposed below). Finally, as has been recognized in list learning research (Anderson and Bower, 1972), the recognition task is complex, involving (especially if the recognition text is a paraphrase of a part of the input text) comprehension of both the input and "probe" text and match of semantic elements generated in response to the "probe" stimulus to corresponding semantic elements remembered from the comprehension of the input.

It remains to outline the scoring methods which have been developed for the base comprehension task. The procedures which will be discussed in detail in Chapters 3 and 10 provide a means for generating a semantic model which represents the "structural meaning" of an input passage which is represented (for scoring purposes) in the form of two directed graphs: one representing the semantic structure and one representing the logical structure (see the example which is analyzed in Chapter 9). The scoring problem is, given this model, to measure correspondences between the "meanings" represented by these graph-structures and the "meanings" conveyed by a subject's verbal reconstruction of the input. The scoring method which was developed involves two procedures: (1) a procedure for scoring reproduced or transformed semantic elements by "template-matching" to the structural model of the input, and (2) a procedure for scoring subject-generated structural elements which do not represent reproduced or transformed input elements. Procedures will now be outlined which were developed, based on the semantic model of Chapter 9, to represent both reproduced and self-generated semantic information.

The reproduced structure is scored on a copy of the graph representation of the text itself. On these sheets each reproduced concept, relation, or proposition is marked with a number indicating the serial position of the sentence in the protocol. Any relation which has been transformed by a subject by application of one or more of the seven operators is marked as so transformed. Scoring the reproduced structure involves principally a process of paraphrasing a protocol to fit it to the structural model of the input text. With some experience, it becomes possible to fit directly (without the paraphrase step). The semantic analysis resulting from these operations results in a rather large set of possible measures. Scores may be obtained indicating the extent to which each defined type of semantic or logical relation has been reproduced or transformed, and how it was transformed. Also obtained for the semantic structure is a measure of the size of each complete sub-structure (in number of connected nodes) and the location of each sub-structure in the semantic hierarchy (level of left-most node). Since in the logical structure, a propositional node can be reproduced, can contain transformed relations, can contain deletions, or can contain self-generated elements (elaborations), counts of reproduced or transformed logical relations must be classified according to the status of each propositional node. The resulting measures summarize the extent to which a person has altered the logical structure in his reproduction.

The analysis of subject-generated structure (i.e. that which is not reproduced or transformed) proceeds in a manner similar to the analysis of an input text. The principal differences have to do with (1) procedures for mapping subject-generated semantic and logical relations into the semantic model of the input text and (2) a list representation of the coded subject-generated structure. From the list representation, it should be possible to reconstruct a subject's protocol in paraphrase.

1.4 Processes in Language Comprehension and Semantic Memory

The methods for representing natural-language discourse semantically and for measuring logico-semantic knowledge acquired from a discourse which have been developed make it possible to represent precisely semantic information input to a subject and to identify the manner in which this semantic information has been operated on or transformed resulting in the protocol which constitutes the subject's output. By systematically manipulating properties (both surface and semantic) of discourses input to a subject and properties of discourse contexts, and by measuring the effects of these properties on semantic outputs, it should be possible to identify processes involved in comprehending and remembering information coded as natural-language discourse. The objective of experiments of this type is to determine the series of cognitive operations which occur during and subsequent to the presentation of a textual input and which result in the protocol obtained from a subject, and to determine how these operations are affected by properties of discourses and discourse contexts. Before considering particular models which have been suggested to account for the processing operations which take place in-between the presentation of a linguistic input to the subject and his generation of a linguistic output, some general statements can be made of requirements which any reasonably complete account of these processes ought to satisy. These general requirements become apparent when one considers the base comprehension task from the point of view of the measurement procedures just described.

A description of the processes which enable a person to perform in the base comprehension (meaning reconstruction) task ought to include three main components. First, it ought to include a structural description of the discourse input to a subject including in that description both surface and semantic properties of the discourse. Second, it ought to include a structural representation of the semantic information in long-term memory (LTM) which results from the subject's processing of the input discourse. Third, it ought to contain a process model consisting of (1) an account of the processing operations which occur during input in generating the semantic information which is stored in LTM, (2) an account of any operations on information stored in LTM, and (3) a description of operations which occur during output, i.e. in verbally reconstructing information acquired from the input discourse. Note that while it is true that a processor can be described in terms of the states of information after each stage of processing input information, a more adequate description should include an account of the processes which result in these successive states of information. The problem, then, is both to describe what is processed (e.g. what are the units or elements of semantic content which are the object of operations in comprehension and memory) and how the processing takes place. One of the most difficult (and most interesting) research problems encountered in trying to develop a process model for the base comprehension task involves inferring processes which occur at input (input processes) from response measures which reflect both input and output processes. As will be seen later, it is possible to make such inferences by fitting certain stochastic growth models which reflect alternative assumptions about processes at input to the data (cf. Chapter 6).

Suppose that a text is presented to a subject and that the text is representable in terms of a semantic structure consisting of an organization of structural elements. Suppose also that the subject is asked to write down his reconstruction of the semantic content of the passage -- the knowledge which he has acquired and retained in comprehending the passage. Suppose in addition that the passage is sufficiently long that any complete reconstruction of the surface features of the passage is rendered extremely difficult. A protocol which is obtained from a subject is likley to have a number of characteristics. For example, a protocol will generally not correspond in its surface features to the input text; it will contain only some of the semantic elements of the input; these reproduced semantic elements may be linguistically represented in paraphrase; reproduced elements present in the subject's protocol will generally not represent a random selection of the input elements; generated semantic elements will be present in subjects' protocols which were never presented explicitly in the input text in linguistically coded form; many generated elements will represent propositions which are inferred from those contained in the input text; and many elements will be transformations of, or distortions of, those contained in the text. Any attempt to model cognitive processes in comprehension and semantic memory will have to account for the presence of elements such as these in subjects' protocols, and for any effects of conditions "external" to the passage itself such as contextual effects, effects of repeated exposure, and forgetting. Observations such as these require (1) that the processor be "generative" (i.e. capable of generating new semantic information from "semantically incomplete" inputs) as well as "interpretive" (i.e. capable of semantically interpreting linguistically coded input information). (2) that the process model account for selection of information either during input or during output, (3) that it account for the verification of generated semantic information against the input, and (4) that it account for information storage and retrieval processes, both short and long term and both at input and at output. Finally, a model also ought to be generally consistent with the stages of processing that have been found to be involved in other kinds of human information processing (e.g. pattern recognition, list learning). A more detailed description of the structural and process components of a general process model for comprehension and semantic memory will now be given in reviewing specific processing models. These components are listed in Table 1.1. A process model which incorporates these components will be presented in Chapter 4.

Specific characteristics of existing process models for comprehension and semantic memory tend to reflect the requirements of the particular task for which the process model was developed. Table 1.2 contains a list of tasks and references to papers presenting models for each task. Existing models may be instructively compared in terms of the components of a general process model. For example, a structural description of the linguistic input is in most cases restricted to representing single sentences (e.g. Clark, in press; Trabasso, 1971; Olson, 1971; Bever, 1970). Winograd's (1972) model does, however, consider "local discourse context", and Rummelhart, Lindsay, and Norman (1971) and Crothers (1970, 1971) and Frederiksen (1972 and the present report) have considered discourses of unlimited length. The last two investigators have concerned themselves principally with a semantic description of input discourse.

1. Structural model of semantic information stored in LTM. A structural description of the semantic information resulting when the processing of the input linguistic string is complete is a part of most models. In most instances the hypothesized structure corresponds to a semantic description of English. In work on list learning (Kintsch, 1972; Rummelhart, Lindsay, and Norman, 1971) the semantic model is used either to specify what information is transferred from a temporary memory buffer to LTM or as a basis for particular retrieval strategies. In work on sentence verification, the semantic structural representation of an input sentence is the central feature of the model, hypothesized processes being concerned principally with either operations on the input to generate the semantic structure or matching operations on the generated structure (Clark, in press; Trabasso, 1971; Olson, 1971, 1972). Different models which are compared in this research often (but not always) differ principally in the semantic representation posited. Computer models (e.g. question answering systems) must specify some formal representation for semantic information. The specific semantic representation adopted has usually been dictated more by the sort of "limited logic" programs designed to operate on the semantic information (cf. Winograd, 1972) than by the semantic properties of natural language which have been described by linguists. However, Simmons (1972) has let semantic characteristics of English be the principal basis for constructing his graph-structure representation of English, and Schank (1971) has been concerned with the general characteristics of a semantic representation and semantic analyzer without being bound by limitations of computer technology. Crothers (1970, 1971) and Frederiksen (1972) have been particularly concerned with comprehensively accounting for semantic properties of English at the discourse level. In developing the semantic model described in Chapter 9, we have been particularly

Table 1.1

Components of a Process Model for Comprehension and Semantic Memory

1. Structural model of semantic information stored in LTM

    a. Semantic structure
    b. Logical structure
    c. Operators

2. Selection processes

    a. Surface (incl. syntactic)
    b. Semantic

3. Interpretive processes

    a. Surface structure generator (incl. morpheme recognizer)
    b. Parser (syntactic processor)
    c. Semantic interpreter (encoder) (incl. retrieval and matching processes)

4. Generative processes

    a. Retrieval from semantic LTM
    b. Operators on semantic information
    c. Matching processes

5. Storage and retrieval processes

    a. Short term memory buffer
    b. Retrieval: undirected search
    c. Retrieval: directed search (incl. operations on semantic information)

6. Operations on semantic information

    a. Lexical
    b. Transformational
    c. Presuppositional (generative)
    d. Inferential (generative)
    e. Elaborative (generative)

7. Matching (verification) processes

    a. Identity match (incl. scanning)
    b. Transformational match (incl. operations on semantic information)

8. Output expressional processes

    a. Surface structure generator

Table 1.2

Tasks for which Process Models have been Constructed or Applied and Papers Presenting Models for each Task

(RT indicates that data considered were response times, RES indicates that data considered were coded responses)

A. List learning

1. General models: Reitman (1970)
2. Recall and recognition: Anderson and Bower (1972a) RES
3. Organization in free recall:

    a. Kintsch (1970, 1972)* RES
    b. Rummelhart, Lindsay, and Norman (1971)* RES

B. Sentence perception

1. Bever (1970) RES

C. Sentence verification

1. Clark (1972), Trabasso (1971), Olson (1971, 1972): structural (*viz*. negation, locatives, comparatives, active and passive sentences) RT
2. Collins and Quillian (1969): conceptual comparisons* RT

D. Judgments of semantic acceptability of sentences

1. Kintsch (1972) RT

E. Recognition confusions in sentence recognition

1. Anderson and Bower (manuscript) RES

F. Question answering

1. Clark (1972) RT
2. Winograd (1972)*
3. Raphael (1968)*
4. Bobrow (1968)*
5. Norman (1972)*

G. Non-verbal reconstruction: following instructions

1. Winograd (1972)*

H. Reading rate and "proposition retention": discourse

1. Kintsch (1972) RES, RT

Table 1.2 (cont.)

I. Base comprehension task: verbal reconstruction

1. Frederiksen (1972, present report) RES
2. Crothers (1971) RES

concerned with representing both semantic and logical properties of natural language discourse by means of a limited set of well-defined semantic and logical relations and operators on those relations.

2. Selection processes. Selection processes refer to any operations which serve to restrict that information which is to be processed. Selection processes are necessary to account for any failure to process all features of the input and thus are central to any account of speech perception. The strategies of speech perception described by Bever (1970) involving segmentation, determining relations between clauses, and labeling input segments are examples of selection processes. Bever describes strategies which are both surface (i.e. determined by surface characteristics of the input string) and semantic. Olson and Hildyard (1972) have considered selection processes in verification tasks and have proposed that the analysis of an input sentence will reflect only those decisions about the input which cannot be made prior to the input of the sentence. Thus information is selected from the surface structure which is relevant to decisions which cannot be specified *a priori* on the basis of context. To the extent that they involve incomplete analysis of inputs, computer parsing routines also involve selection processes (cf. Winograd, 1972). Semantic selection could occur if the parser were under the control of a semantic processing component of the program.

3. Interpretive processes. Interpretive processes are responsible for "decoding" the input string resulting in a syntactically processed and semantically interpreted informational input. Interpretive processes have been a major constituent of virtually every model. Winograd (1972) presents a review of computer parsers and a description of his own parser which utilizes semantic operations as a part of the interpretive process (e.g. to resolve ambiguities). Winograd's parser is also unique in its use of "systemic grammar" (Halliday, 1967, 1970) which is designed to provide an heuristic input to a semantic system. Winograd's semantic structure into which the parser maps, is not particularly well developed from the standpoint of a generally applicable semantic description of English discourse. Bever's (1970) accounts of processes in speech perception assign a central role to syntactic processing in segmentation of the input string, and also considers the semantic interpretation to be important in speech perception. Sentence verification models always consider the transforming operations which are required to make a "semantic match" between two inputs. These operations include syntactic (e.g. passive to active) as well as semantic operations. Clark (in press) considers generative processes (generation of presuppositions) in his models for sentence verification (e.g., re. different types of negation). The model which will be developed in Chapter 4 supposes that both interpretive and generative processes occur at input. In the present work, a central question will be to determine what task characteristics induce a person to process textual inputs "interpretively" or "generatively".

4. Generative processes. Generative processes refer to operations which result in semantic elements being incorporated into the semantic structure (associated with a linguistic input) which were not "present" in the input in linguistically coded form. Generative processes include retrieval of semantic information corresponding to input lexical elements, operations on stored semantic information (e.g. inference), and matching processes involved in the verification of generated semantic information against "data" selected from the input. The computer models which have been suggested are essentially interpretive processors, although Winograd's (1972) parser allows for the semantic component to intelligently augment the parsing. Rummelhart, Lindsay, and Norman's (1972) program treats retrieval as "rational" (i.e. directed search), and Kintsch (1972) considers the transfer of information from a memory buffer to LTM in list learning tasks to be systematically based on retrieved semantic information corresponding to lexical elements of the list. Clark's (in press) models for sentence verification involve the generation of presuppositions corresponding to certain input sentences and the use of the generated presuppositions in matching against a second input. Three authors have emphasized the importance of generative processes in language comprehension and memory. Schank (1971) regards comprehension as a prediction problem involving the generation of a semantic model of an input. "In order to effectively analyze a given linguistic input, it is necessary to make predictions as to what the input might look like, compare the actual input to the expected input, and coordinate both with the memory model" (Schank, p. 109). Kintsch (1972) focuses on information storage and retrieval problems and argues that for economy of storage, semantic structures will be stored from which information can be generated (e.g.) by means of inference rules. In the present work, we will be especially concerned that a model be capable of accounting for the frequent occurrence of inferences in subjects' free recall protocols. The model presented in Chapter 4 involves generative processes both in semantically interpreting linguistic inputs and in generating semantic elements not corresponding to explicitly coded input elements. To determine whether or not generative processes involving inference and elaboration were occurring at input, in Chapter 6 we will analyze correlated growth in reproduced (corresponding to input semantic elements), inferred, and elaborative semantic response measures by fitting alternative stochastic growth models associated with alternative assumptions about the occurrence or nonoccurrence of generative processes at input to the data. The results will be seen to support the notion that generative processes do occur at input.

5. Storage and retrieval processes. Storage and retrieval processes are involved whenever input information is processed, since processing takes time and thus information must be stored in order to be processed. While memory models developed to explain list learning phenomena are available (e.g. Reitman, 1970; Anderson and Bower, 1972a; Atkinson and Shifferin, 1971), models which consider the structure of stored

semantic information and which consider memory processes in comprehension have been proposed only recently (cf. Collins and Quillian, 1969; Rummelhart, Lindsay, and Norman, 1971; Kintsch, 1972; Anderson and Bower, 1972). Among psycholinguists, there appears to have been an unwillingness to seriously consider memory processes in comprehension at all (e.g. Carroll, 1971). Of the above models of "semantic memory" processes, Rummelhart et al. (1972) and Kintsch (1972) have attempted to use their models of semantic memory structures in conjunction with process assumptions to account for free recall list learning results; and Anderson Bower (1972) have been concerned in addition with accounting for recognition memory for sentences. All of the above models of semantic memory processes incorporate (1) a process for "maintaining input" (rehearsal), (2) a limited capacity short term memory (STM) or buffer storage, and (3) a long term memory (LTM) of practically unlimited capacity and the contents of which may be represented by means of a semantic structural model. The models differ in their treatment of the role of STM limitations in the selection and definition of what is stored, the role of retrieval processes during input, the kinds of retrieval processes considered (e.g. directed vs. undirected search of LTM, development of retrieval cues), bases for forgetting, matching processes, and of course the structure in LTM which is searched. In the present research, recall protocols will be obtained after repeated exposures to a discourse to facilitate the systematic study of processes by which a memory structure is "built up" in LTM and the role of previously stored semantic structures in the acquisition of new information.

6. Operations on semantic information. Operations on stored semantic information are involved in retrieval; in semantically interpreting input lexical elements; in transforming input information (e.g. by applying operators to previously input relational structures); in inference: inferring relational structures from previously input relations, or from structural representations of lexical elements, or both; in generating presuppositions (highly probable "inferences"); and in generating elaborative relational structures. To the extent that models have been "interpretive" rather than "generative", operations on stored semantic information have not been considered (especially during input) or have been considered only in a limited way. In addition to the work discussed under "generative processes above, operations on stored semantic information have been a central component of computer question-answering systems such as those of Bobrow (1968, algebra story problems); Raphael (1968, limited logic re. statements of set relations, part-whole relations, etc.); and Winograd (1972, spatial relations).

7. Matching (verification) processes. Matching processes have been extensively studied in the research on sentence verification, much of which has already been discussed. In addition to this work, Anderson and Bower's (1972b) computer program extensively develops matching processes as it tries to find paths in a semantic structure in LTM to

correspond to a structure which is input. A particularly interesting problem which they deal with is that of imperfect matches involving semantic "trees" in LTM which imperfectly correspond to input "trees" and the use of this imperfectly matched information in subsequent processing.

8. Output expressional processes. Output expressional processes are involved in linguistically encoding semantic information to express acquired or generated semantic information as discourse. Expressional processes have not been considered seriously in most work on comprehension since either the tasks used do not involve meaning reconstruction, or (especially in computer models) output expressional processes are not of immediate interest to the author. There appears to be a growing consensus that a model of comprehension cannot be based on processes of speech production and that a linguistic description based primarily on considerations of speech production is not likely to be optimal for purposes of developing a semantic representation of natural language.

One of the principal shortcomings of process-oriented research in comprehension and semantic memory is that either the models suggested have a good basis in experimental data but are limited to very specific tasks, or they are less task-restricted by have a very poor basis in empirical data (especially the computer models)

1.5 Effects of Surface and Semantic Properties of Discourses and Discourse Contexts

Much of the voluminous research on language comprehension and learning from "meaningful verbal discourse" has been concerned more with determining what properties of linguistic material or factors in the context within which the linguistic material is presented are related to the "degree" or "amount" of comprehension or learning which takes place in response to an input discourse rather than with determining the sequence of processing operations which take place or the representation of information in LTM. Carroll (1971b) has prepared a very extensive review of that literature on comprehension and learning from discourse from the former point of view. While much of the research reviewed by Carroll is not process-oriented, the results are important to the extent that they identify specific characteristics of discourses or discourse-contexts which affect outputs related to the processing of that discourse. Carroll's review includes topics such as the following: (1) studies identifying properties of single sentences which affect performances involving those sentence types such as: length; grammatical structure including: phrase structure constituents, grammaticalness, grammatical "complexity", syntactic anomaly; semantic anomaly; relative roles of syntax and semantics; order of approximation to natural language; (2) studies of effects of factors of content and organization in discourse; (3) studies of effects of stimulus modality (visual vs. auditory presentation); (4) studies of effects of other presentation factors such as speech rate, compressed speech, and distractions during listening; (5) studies identifying variables affecting (long term) learning from discourse (usually measured by multiple choice tests or verbatim recall) such as (a) "meaningful" vs. "rote" instructions; (b) intentional vs. incidental learning; (c) effects of "advance organizers" and other kinds of contextual information or instructions; (d) effects of length-time relationships, word frequency, and repetition; (e) effects of content, organization, sequencing, and other semantic characteristics of a discourse; and (f) post-presentation variables such as delay of recall and recognition. Carroll's review is extremely useful as a catalogue of characteristics of linguistic inputs and task characteristics which have been found to influence performances based on these inputs. Carroll's review does not consider recent work on linguistic semantics relevant to comprehension, recent work on semantic information processing, or more recent work on semantics and comprehension reviewed by Clark (in press). Carroll's review also does not consider developmental studies or research concerned with inferential processes in language processing. It is interesting to note from Carroll's review the almost total absence of systematic experimentation on effects of semantic-structural properties of discourse on comprehension and memory. Of the studies which are reviewed, the most relevant to this problem are those concerned with establishing that information concerning syntactic "deep-structure" characteristics of sentences is used in understanding or remembering those sentences, and those attempting to show that in recognition subjects make confusions between sentences which are similar in meaning ("gist") but differ in "deep structure." The paper of Clark (in press) thoroughly reviews research employing verification and question-answering tasks with the objective of identifying a process model and semantic representation which is capable of explaining performance on these tasks; and Fodor and Garrett (1966) have reviewed experimental work concerned with establishing a relationship between the "derivational complexity" of sentences (re. generative transformational grammar) and processes in sentence comprehension and memory.

A number of recent studies are concerned principally with the structure of semantic information in LTM and are not described in the previously cited reviews. These include: Kintsch's (1972) experiments on semantic acceptability of sentences and on reading times for sets of propositions (Kintsch and Keenan, 1972), Anderson's (described in Anderson and Bower, 1972b) experiments on recognition confusions in sentence memory, and recent work on sentence verification (Trabasso, 1971; Olson, 1971, 1972) and on verification times for semantic relations defined on word pairs (Collins and Quillian, 1969; Rips, Shoben and Smith, 1972; Smith, Haviland, Buckley, and Sack, in press) Kintsch (1972a) varied both semantic properties of sentences (definitional, contingently true, contradictory, and nonsense) and syntactic form (copula-noun, copula adjective, and verb), and measured true-false verification times. He found that "if subject and predicate are strongly related in an acceptable sentence, reaction times are faster (definitional sentences) than if the relationship is less close (contingent sentences); for unacceptable sentences this relationship is reversed." Kintsch found no effect of syntactic form class. A process model was also presented to account for more precise quantitative properties of the data. The studies of Collins and Quillian (1969) and Rips et al. (1972) also explore the hypothesis that processing times may reflect semantic properties of elements stored in LTM. In the case of Collins and Quillian the structural feature of information stored in a semantic network in LTM studied is the number of nodes intervening between two concepts. Rips et al. argue against the network definition of "semantic distance" but their argument appears to indicate only that Collins and Quillian's network is not sufficiently complex. The general result is that as semantic distance is increased between the subject and predicate, reaction times for judgments of semantic acceptability increase. In another study (Smith, et al., in press), evidence was obtained from measures of response times for true-false verification of previously learned noun-number pairs in which the nouns were organized hierarchically into classes, which was interpreted as indicating that both storage space and retrieval complexity determine what retrieval process was adopted by their subjects -- direct retrieval (directly reflecting the organization of the noun hierarchy) or deductive retrieval (operating deductively on the noun hierarchy).

In another experiment designed to demonstrate that the propositional base (semantic) structure of a sentence has demonstrable effects on processing time, effects not attributable to such surface features as length and syntactic factors, Kintsch and Keenan (1972) measured reading times for sentences of constant length and differing propositional (semantic) structures. When reading time was plotted as a function of number of propositions recalled, it was found that each added proposition increased reading time by an approximately constant amount. Internal analyses of the data indicated that the effect was not entirely due to syntactic factors. These experiments leave little doubt that semantic characteristics of lexical items, sentences, and discourse have important effects on performance.

Anderson (reported in Anderson and Bower, 1972b) has attempted to obtain data from recognition memory experiments which could help resolve the issue of what surface sentences to consider to be synonymous, i.e. members of the paraphrase set represented by a single semantic structure in LTM, by examining recognition confusions in sentence memory. The task which Anderson employed was a four-alternative forced choice recognition task where his interest was in comparing false alarm rates for different incorrect choices. The assumption was that if two sentences are mapped onto the same semantic structure, they will be confused in later recognition if, first, separately stored syntactic information is "wiped out" by exposure to interpolated material during the delay between presentation of a sentence and presentation of the "probe" sentences. On the basis of his results, Anderson concluded that the range of surface forms which ought to be regarded as "equivalent" is much broader than one might expect. However, there are reasons to reserve judgment on such a conclusion which is based entirely on sentence recognition data. The use of memorial techniques to assess structural identity of representations of sentences stored in LTM has been criticized by Fillenbaum (1970) on the grounds that evidence based on confusions in recognition are only indirectly related to the underlying representations in LTM. That recognition confusions can reflect specific events in sentence comprehension and recognition which in turn affect what is stored is illustrated by Tieman's (1971) dissertation in which different instructions (*viz*. "remember the wording" vs. "generate images") were found to have a greater effect on recognition errors for comparative sentences than did properties of the comparative sentences employed. In view of the difficulties involved in making absolute statements about the form of information stored in LTM from sentence recognition studies, it may be desirable to consider other tasks which may provide more direct information concerning the structure of semantic information stored in LTM.

Sentence verification tasks have also been employed to infer properties of the representation of linguistic information resulting when a sentence is comprehended (cf. Clark, in press). The method adopted assumes that a person's reaction time is a sum of durations of processing times for independent serial processes associated with "encoding" input information into internal representations and with matching these representations against other representations. The form of the internal representation obviously plays a major role in determining the series of operations involved in interpreting inputs and in matching (e.g.) representations generated for pairs of sentences. As in the case of sentence recognition studies, the nature of the representation in LTM appears to be influenced by specific characteristics of verification tasks. For example, Trabasso (1971) has fit alternative process models for the verification of negative sentences (a "response change model" and an "optional recoding model") to new data and to previously reported data from a variety of sentence verification studies and concluded that subjects adopt alternative processing strategies depending on characteristics of the tasks and sentences processed which are related to the number of options or alternative states open to the subjects. Clark (in press) independently came to the same conclusion comparing identical models (which he called "true" and "conversion" models of negation). Olson (1971) has investigated this problem developmentally finding that the "recoding strategy" occurs later than the "response change strategy". He concluded that "the number of mental operations is determined by the set of alternatives considered by the listener-reader". In another study, (Olson and Hildyard, 1972) processing times for verifying active and passive sentences were considered to depend only on the time required for decisions which cannot be presupposed prior to presentation of a sentence. In this experiment the voice of the verb of the sentence being verified was specified by the context (by "foregrounding") with the resulting decision time associated with voice being reduced to zero. Thus, there is substantial evidence from sentence verification studies that the extent of processing of sentences, and hence the form of information resulting from those processes, is related to specific informational characteristics of a task and context-related presuppositions. The resulting conclusion that the form in which semantic information is represented in LTM is a *relative* matter is an important contribution to our knowledge about comprehension. The possibility remains that there is a "most probable" form which occurs under a great many task and contextual conditions. If this is so, then it would seem to be important to attempt to determine the probable form of semantic representations resulting from comprehension of sentences embedded in natural discourse contexts and unaffected by the processing of subsequently presented probe inputs.

It may help in identifying just what combinations of tasks, measures, and experimental variables have been studied in research on comprehension to present a systematic classification of tasks, response measures, and independent variables which have been used (or may be used) to study information processing in comprehension and semantic memory. The classification in Table 1.3 is by tasks, response measures, and independent variables lending themselves to experimental manipulation. The *tasks* are classified first as involving either a *choice response* or a *free verbal response*, and second as involving either *single inputs* or *multiple inputs*. Within this general two-way classification specific tasks are identified. Not included in the free response tasks listed are those requiring verbatim reconstruction (since they do not meet the minimal requirement for demonstrating comprehension -- paraphrase) and those tasks which alter the base task of uninterrupted presentation of an input discourse. It may be seen that *practically all research on comprehension has employed choice response tasks*. This fact seems to be in part due to lack of an adequate solution to the scoring problem discussed previously. *Measures* which may be obtained are classified with respect to the task for which they can be obtained -- choice response tasks or free response tasks. For choice response tasks, both response patterns and response times have been employed. The *variables* identified in Table 6 for single inputs include surface (e.g. grammatical) characteristics and semantic characteristics. The great majority of psycholinguistic studies have been concerned with grammatical or certain semantic characteristics (e.g. negation, locatives, comparatives) of single sentences. Also considered have been characteristics of inputs such as word frequency, length, and "imagery value". An unsolvable design problem for experiments attempting to manipulate input variables such as these is the mutual *inter-dependence* of discourse characteristics which is built into languages and which makes it impossible to manipulate one independently of another. For example, it is virtually impossible to vary a semantic characteristic of a linguistic input

Table 1.3

Tasks, Response Measures, and Independent Variables for the Experimental Study of Information Processing in Comprehension and Semantic Memory

TASKS

I. Choice Response Task

- A. *Single input*: verification of semantic acceptability
- B. *Multiple inputs*:
  - 1. probe retrieval
    - recognition
    - choice recognition
    - question answering: yes/no
  - 2. verification
    - match/no match
    - choice verification

II. Free Response Task

- A. *Single input*:
  - 1. paraphrase
  - 2. meaning reconstruction
  - 3. operations on input
  - 4. reading time
- B. *Multiple inputs*:
  - 1. question answering: wh-questions
  - 2. structured deletions
  - 3. meaning reconstruction
  - 4. operations on input
  - 5. reading time

MEASURES

I. Choice Response

- A. *Response pattern*:
  - 1. binary
  - 2. multi-category
- B. *Response times*

Table 1.3 (cont.)

II. Free Response

- A. Reproduced structure:
    - 1. surface features
    - 2. logico-semantic features
- B. Generated structure: [classified by operations which generated the structure]
    - 1. surface features
    - 2. logico-semantic features
- C. Serial order in output
- D. Response times

INDEPENDENT VARIABLES

I. Single Input

- A. Surface characteristics:
    - 1. length
    - 2. surface structure
- B. Semantic characteristics:

1. content	conceptual relational
2. structure	semantic logical

- C. Temporal conditions
- D. Structured deletions
- E. Response required at input
- F. Context

II. Multiple Inputs

- A. Single input variables for each input
- B. Relations between successive inputs:
    - 1. identity
    - 2. surface transformations
    - 3. semantic relations
- C. Temporal conditions between successive inputs
- D. Interpolated material
    - 1. none
    - 2. present

without also varying a surface characteristic, although there is some limited freedom to pick surface sentences from among the "paraphrase set" associated with a single semantic structure. The only satisfactory solution to this problem appears to be to adopt a strategy of "representational design" (Brunswik, 1949) involving sampling linguistic inputs from a set of inputs which have in common only the syntactic or semantic property which is under investigation and which vary with respect to other characteristics.

In the present research, we have worked entirely with free response tasks involving meaning reconstruction. Single inputs were used. Measures obtained (including those described previously) consisted of measures of reproduced structure, generated structure, and serial order in output. Experimental variables manipulated involved the context in which the input was presented. By adopting free response tasks, we eventually hope to be able to get direct information concerning the form and content of information represented in LTM resulting from comprehension of sentences embedded in a discourse context, to be able to determine parameters characterizing discourses and discourse contexts which affect the form of this representation, and to be able to gather information concerning specific operations which occur in processing an input discourse.

Research on language comprehension and semantic memory employing free response tasks has been undertaken only recently by Crothers (1970, 1971) and in the project described in the present report. Although there has been research reported concerning effects of properties of discourses consisting of multiple sentences on information acquired from the discourses; with distortion of meaningful materials in remembering; and with effects of specific cognitive operations on the content of a text, advance organizers, instructions, and prior instruction on recall of elements taken from a text (cf. Carroll's review, and (e.g.) Frase, 1966; Dawes, 1966; Bartlett, 1932); either the tasks employed have been choice response tasks or they have involved verbatim recall. This research also has not employed any formal procedure for representing the "meaning" of the textual inputs used. In both Crothers' project and the present one, extensive work has been done on the twin problems of developing a logico-semantic structural representation of discourse and of scoring subjects' recalls semantically against the structural model of an input discourse.

Crothers (1971), working with single paragraphs adapted from encyclopedia entries for nebula and oceanography, has developed a form of semantic representation which emphasizes a hierarchical representation of the paragraph and which contains substantial semantic information which is inferred, i.e. information which is not represented explicitly in the surface structure of the passage but which is derivable from explicitly represented information. One of his principal goals in undertaking a structural analysis is to develop a semantic representation from which an "abstract" of a passage can be easily obtained by "pruning off" the more subordinate branches. Psychologically, this goal was motivated by the informal observation that in reconstructing a passage, one starts with the "gist" (superordinate structure) and then proceeds to reconstruct the details (branches). However, Crothers found that this "gist hypothesis" was not supported by his data based on the nebula and oceanography passages. Crothers also found that the related hypotheiss that "terminal (i.e. most subordinate) subtrees" are recalled less well than the main subtree was not supported by the data. In addition to these results, Crothers study found (1) that frequency of occurrence of a node within the structural model of a passage (both explicit and implicit occurrence) was related to the number of subjects recalling a node, (2) that sentence order did not appreciably affect recall, (3) that forgetting is not mainly restricted to embedded clauses in the surface structure, (4) that the major subtopics (hierarchies) were recalled independently of one another. The above results were based on an analysis of response patterns consisting of scores indicating whether a node was correctly recalled in a subject's protocol.

1.6 Organization

Part I of the present report presents results concerning the effects of experimental contexts which were obtained using the first procedure developed for measuring semantic information acquired from a discourse. Chapter 2 contains a description of the rationale for the study, reviews relevant research, and outlines the specific questions to be investigated and the sources of data relevant to these questions. Chapter 3 presents a description of the conventions which were first adopted for representing semantic structural information "contained" in a discourse and a description of the scoring procedures which were developed based on these conventions. Also identified are the semantic classes of responses in reconstructed discourse which result from the application of these scoring procedures. Interscorer reliabilities of frequency scores based on these response classes are also reported. To facilitate description and interpretation of our results, and to make explicit the process assumptions underlying the quantitative analyses of the data which were undertaken, Chapter 4 presents a detailed description of the process model which was developed during the course of the research. Considered in the model are processes involved both in generating semantic information from a natural-language discourse and in reconstructing information acquired from a discourse. Relationships between specific processing operations and classes of response in reconstructed discourse are discussed. Two principal questions are identified with which the present study is concerned: the relative extents and roles of interpretive vs. generative processing operations in "normal" comprehension, and the extent of invariance of these processes over characteristics of discourses and discourse contexts (process invariance). Chapter 5 presents the principal experimental results concerning the effects of discourse contexts designed to induce certain processing operations on semantic information contained in a discourse, on response class frequencies reflecting the relative extent of specific processing operations. Results concerning changes in these effects associated with repeated exposures to the discourse are also presented.

In order to investigate possible alternative sources of observed growth in inferred and elaborative relations which might reflect the occurrence or nonoccurrence of generative processes during input, stochastic growth properties of repeated measurements of frequencies of different classes of semantic relations were also studied. It was assumed in the analysis that if new semantic information is acquired at input and that generative processes do occur during input, then observed growth in subject-generated semantic elements should not be due solely to growth in the reproduced (explicit) structure. Alternatively, if the person behaves entirely as an "interpretive" processor, then subject-generated semantic elements will be produced only at output and thus observed growth in subject-generated elements ought to be attributable solely to growth in the reproduced structure. These two alternatives were studied by fitting alternative Markov simplex growth models (Jöreskog, 1970) to the matrix of intercorrelations of frequencies of reproduced, inferred, and elaborative semantic relations. Each stochastic model mathematically expresses the quantitative consequences for correlated growth data of a particular model. The results are presented in Chapter 6. In addition, effects of the experimental contexts on the goodness-of-fit of the alternative mathematical models was found to be very informative. Since this comparative model fitting technique appears to be useful not only for investigating alternative sources of growth, but also for investigating alternative semantic structural hypotheses, included in Chapter 6 is a description of how linear structural models such as the Markov simplex model may be used to investigate semantic structural hypotheses and a description of a generalized normal ogive model which should permit one to investigate such questions at the level of individual response patterns obtained for semantic structures corresponding to particular sentences or sentence-sequences.

Another kind of question which will be studied in Chapter 7 concerns sources of individual differences in semantic information recalled or generated (and hence in the sequence of information processing operations resulting in that information), and effects of characteristics of discourses and discourse contexts on sources of individual differences. Sources of individual differences may be investigated correlationally by obtaining measures of specific narrowly defined "abilities" and studying predictive relationships between these measures and measures obtained from scoring subjects' recall protocols. Analysis of the effects of discourse characteristics involves considering experimentally-induced differences in ability-response class correlations. A rationale for this approach has been suggested earlier

(Frederiksen, 1969) involving interpreting a high correlation between a specific ability measure and response class as indicative of the particular process or processes involved in generating responses of that class. This method of studying individual differences in experimental contexts has been applied extensively in educational research and has been labeled by Cronbach and Snow (1969) the "ATI" approach for "aptitude-treatment-interaction". Thus, sources of individual differences were studied by attempting to predict frequencies of each class of response from measurements of abilities and studying the effects of the contexts on these predictive relationships. In the present research, processes in comprehension and memory were classified into input linguistic processes, unconstrained generative processes (associated with elaborative production), generative reasoning processes (associated with inferential production), output expressional processes, storage and retrieval processes, processes associated with buffer storage, and processes associated with the identification and maintenance of semantic elements. Ability measurements related to each of these classes were obtained and used to predict response class frequencies separately for each experimental context. Data were also obtained to attempt to determine to what extent individual differences in strategies for acquiring and organizing semantic information occurred and to investigate context effects on such strategies. Predictive relationships between strategy measures and response class frequencies were also investigated to determine which strategies were associated with specific classes of acquired semantic information and under which experimental contexts.

Part II contains a detailed description of the structural model which was developed to represent the logico-semantic structure of a discourse (Chapter 9) and a description of the scoring procedures which were developed based on the structural model (Chapter 10). Some results obtained using this scoring procedure are also presented in Chapter 10. Since an important aspect of this research has been the development of procedures for measuring semantic knowledge acquired from a discourse, the descriptions of these procedures are intended to be as explicit as possible.

PART I

CHAPTER 2

LEARNING FROM DISCOURSE IN ARBITRARY AND NON-ARBITRARY CONTEXTS

By what process is an individual able to acquire semantic knowledge from natural-language discourse? How and in what form is such acquired information stored for subsequent use? By what means is such stored semantic information made available for use in new situations long after it has been acquired? It is hard to think of issues more central to an understanding of cognition, learning, and psycholinguistics, especially when one reflects on the fact that most of the learning which takes place during a person's lifetime occurs in response to verbally transmitted information: transmitted in messages usually consisting of more than one sentence. In fact, it is hard to imagine a task which does not require a person to retrieve and use previously acquired semantic information. Given the obvious importance of the capabilities referred to in these questions, it is surprising how little is known about these processes. We do know quite a bit about the components of memory, but only very recently have students of memory begun to seriously inquire into the organizational properties of information stored in memory (e.g. Norman, 1972; Kintsch, 1972). While we do know that structural properties of sentences may be processed at many levels (e.g. Bever, 1970), we still lack an understanding of the specific processing operations that occur which enable a person to interpret single sentences semantically. At the discourse level, even less is known about these processes. The usual assumption appears to have been that a discourse would be processed in the same manner as the individual sentences from which the discourse is composed. Research on language comprehension has tended to emphasize the immediate processing which occurs as a sentence is input and "understood," and not to consider seriously questions involving memory, such as: "How is stored semantic information made available for use in interpreting an input sentence?" and "By what processes does semantic information acquired from one sentence affect the interpretation of subsequent sentences?"

It would appear, then, that any satisfactory experimental attack on these problems will have to seek to identify specific processing operations that are involved in acquiring _and retaining_ non-verbatim (semantic) knowledge from natural-language _discourse_. Thus, from this point of view, an attack on these problems should simultaneously consider the psycholinguistic and the memorial aspects of the problem. These two aspects--the psycholinguistic, concerned principally with immediate processing of sentences, and the memorial, concerned with processes of storage and retrieval and with the organization of information in long-term memory--should both be incorporated in any attempt to model the processes involved in knowledge acquisition from discourse.

The next question, then, is "What sort of experimental task is most likely to accomplish these objectives?" A number of task characteristics are clearly necessary. First, the tasks should involve the uninterrupted presentation of a natural-language discourse. Second, the conditions of presentation and the discourse itself should be representative of naturally occurring discourses and of natural conditions in which discourses are received. Third, some assessment of the semantic information which has been acquired should be made, both immediately after a discourse has been presented and at the end of some retention interval. Assessment of acquired knowledge can be made in more than one way (e.g. probe retrieval: recognition, choice recognition, question answering; or recall: recall of items contained in a presented discourse, paraphrase, meaning reconstruction; see Table 1.3), but however the assessment is made, it is necessary that the semantic information contained in the input discourse be unambiguously and completely specified. With the exception of Crothers' (1972) study described in Chapter 1, there has been virtually no research on the acquisition of non-verbatim semantic information which is contained in a text and which is to be acquired. However, there have been an extensive number of studies reported which are concerned in various ways with "meaningful verbal learning" in which the learning task does not involve verbatim memorization. Since the principal interest in most of these studies has been in the effects of particular experimental variables on the amount of "learning" from a discourse, in practically all of these studies only a single global measure of "information acquired from a discourse" was obtained. Since it is only by means of observations of precisely what information an individual has acquired from a discourse that we can infer how an individual has processed an input discourse in acquiring that information, these studies provide very little specific information about these processes. The studies do, however, provide a general description of the sorts of variables which effect various global indices of amount of semantic information acquired. For a review of studies of the effects of such task variables as rote vs. "meaningful" instructions, length, time, frequency, repetition, organization, sequencing, length of retention interval, and incidental vs. intentional learning on various global indices of acquired semantic knowledge see Carroll (1972) and Welborn and English (1937).

Among studies which measure "meaningful learning" by a single index of amount of acquired knowledge, certain studies of the effects of advance organizers, contexts, adjunct questions, and other conditions which are designed to induce specific processing operations on semantic information contained in an input discourse are more informative about processing activities in the acquisition of knowledge from discourse (cf. Ausubel, 1967; Rothkopf, 1962; Gagné and Wiegand,1970; Carroll, 1972). The principal value of these studies is that they indicate that there are experimental conditions which have demonstrable effects on amount of non-verbatim knowledge acquired from a discourse: effects which appear to indicate that subjects' processing activities adapt to passage and text characteristics and that these activities include a variety of "superordinate" operations on the logico-semantic content of a text. These studies include Rothkopf's series of experiments on the effects of interspersed questions designed to induce particular processing activities in "meaningful learning" from prose (cf. Rothkopf, 1972; Frase, 1968; Carroll, 1972), Gagné and Wiegand's (1970) study of effects of context sentences immediately preceding facts to be learned, Ausubel's (1960, 1967) studies of effects of "advance organizers," and studies of interference effects in acquisition of non-verbatim information from discourse.

The rationale underlying Rothkopf's experiments is that questions interspersed in a text which require that a subject search recently stored information acquired from the text may influence a variety of processing activities which facilitate the acquisition of information from the text. Thus, in Rothkopf's view, a question has two sorts of instructive effect: a direct effect due to the increased likelihood that a subject will store the interrogated information and an indirect effect on "the various processing activities which subjects engage in while confronted with text" (Rothkopf, 1972).[1] The evidential basis for this claim is the finding that questions affect the acquisition of information other than that narrowly required to answer the adjunct questions. To make certain that acquisition of the interrogated information has no direct effect on acquisition of information to be used to assess the second sort of effect of questions, in a separate experiment subjects are trained on the "interrogated" parts of the text and then tested on the other parts to insure that no positive transfer occurs. In general, positive effects of questions on amount of information acquired which was independent of the questions, were produced only by questions that followed exposure to the relevant material. Rothkopf and Bisbicos (1967) also found that the nature of the adjunct questions influenced the nature of the specific knowledge acquired. Rothkopf has deliberately avoided speculating about the particular processes which he is influencing in his experiments because of his feeling that conclusions in this area are limited by a lack of adequate experimental measures.

Gagné and Wiegand studied the effects of particular context sentences placed immediately before sentences expressing information to be learned. The contexts conveyed "superordinate," "coordinate" (related), or "unrelated" information, or no context was present. The contexts were found to affect recall differentially. Greatest recall was found with no context, followed by superordinate, coordinate, and unrelated contexts in that order. However, no effects were observed on recognition.

Ausubel and his collaborators (Ausubel, 1960, 1967; Ausubel & Fitzgerald, 1961, 1962; Ausubel & Yousef, 1963, 1966) have argued that "meaningful" learning necessarily involves relating acquired information to previously acquired knowledge ("cognitive structures") in a nonarbitrary and nonverbatim manner. Ausubel's studies have not sought to specify the precise nature of these structures; rather they have attempted to facilitate "meaningful" learning by manipulating that knowledge which is available to a subject to which new knowledge can be related. His experiments involve the presentation of "advance organizers" -- introductory discourse material presenting new generalized concepts under which information to be learned can be subsumed, or clarifying distinctions which distinguish the new information from previously acquired knowledge -- and investigating the effects of advance organizers on the amount of new information acquired. Results have generally appeared to support Ausubel's notions concerning the importance of advance organizers in the acquisition of non-verbatim knowledge from discourse.

Since these experiments with advance organizers fall within the interference paradigms of list learning research and since the predicted effects have generally been facilitative, it is of interest to determine if there are conditions under which inhibitory effects can be produced. In fact, inhibitory effects appear to be rather difficult to produce in learning tasks involving nonverbatim learning from discourse. Inhibitory effects have been produced only with difficulty and only in studies of retroactive interference (RI). One major difficulty in this area is in defining a measure of the similarity of the originally learned passage and the interpolated passage. Any adequate solution to this problem would appear to require a well-defined semantic model of both the original and the interpolated passages. A second difficulty involves measuring the degree of learning of the original and interpolated passages. What is needed is a means of precisely measuring that information which has been acquired from an input discourse, and that input information which has been altered or transformed as it is acquired. Furthermore, a taxonomy of "intrusions" is needed if one is to distinguish subject-generated semantic information from that information which is generated in response to the interplated passage. For these reasons any results in this area must be regarded as only suggestive.

Few studies have succeeded in demonstrating RI with connected discourse materials which have required substantive (non-verbatim) recall. Mehler and Miller (1964) presented lists of eight sentences for free recall and scored subjects' protocols with both verbatim and content criteria. Interpolated sentences were constructed to provide either syntactic interference (different groups were presented eight sentences at one of three degrees of syntactic similarity) or semantic interference (eight interfering sentences representing each syntactic type in the original list were presented such that each interfering sentence was completely unrelated to the originals in meaning). Two degrees of original learning were used. Syntactic and semantic interference were produced when the verbatim criterion was used for both degrees of original learning. But when the content criterion was used, substantial syntactic facilitation was produced at the lower degree of original learning. Mehler and Miller interpreted their results as being consistent with the idea that semantic information and syntactic details were acquired separately (in that order) and presumably stored separately.

Entwisle and Huggins (1964) tested engineering students on principles of electrical circuit theory which they had studied. Interpolation of a highly similar set of principles before testing produced inhibitory effects. However, it is reasonable to suspect that there was a significant rote memory component to these tasks. Ausubel, Stager, and Gaite (1968) attempted to produce conditions which would result in inhibitory effects of a second interpolated passage on nonverbatim knowledge acquired from a previously presented passage (RI). They found that two variables, degree of interpolated learning and overlearning of the original material, both facilitated the retention of information acquired from the original passage. They attributed the facilitating influence to possible rehearsal and clarification of the original material induced by the interpolated message. Finally, Crouse (1970) defined similarity of the orignal and interpolated texts in terms of similarity of questions generated from either passage (same questions, different answers). With highly similar interpolated passages so defined, he produced a modest amount of RI. However, the answers to the questions which he used appeared to have an arbitrary (rote) character which make the study unconvincing as a study of "meaningful" learning. These studies of effects of advanced organizers, contexts, adjunct questions, and interpolated texts leave little doubt that "contextual" factors, post-presentation factors, and such factors as adjunct questions affect processing activities involved in acquiring semantic information from discourse, processing operations which appear to be substantially different from those operating in rote memory tasks involving discourse.

A major shortcoming of the studies which have been described thus far is that they provide very little information about precisely what was affected by the experimental conditions. For example, Rothkopf (1972) has observed that "serious theory building is at present limited by the sparse measurement techniques that are available to us. Anyone who has ever conducted an experiment on learning from written text is struck by the mute and unrevealing posture of the reader. The processes that must be taking place have to be inferred from crude learning measures or from inspection of time data in a very indirect manner" (p. 332). While there has been some theoretical work concerned with developing a process model for natural language comprehension and semantic memory (see Chapter 1), it appears as if our ability to develop an adequate data base for such a theory depends on the development of an adequate procedure for measuring precisely what semantic information a subject acquires (or generates) when presented with a discourse. With the exception of Crothers (1972) study and previously described studies of recognition memory for sentences, there is very little research providing information concerning either the acquisition of specific semantic elements from a discourse or the effects of possible processing operations on presented semantic information which might be reflected in the presence of semantic information in subjects' protocols which is derived from, but not identical to, information which was explicitly coded in the presented text. However, there are two lines of work which are relevant to these problems, both of which have attempted to represent the semantic content of a discourse in the form of a relational structure which a discourse imposes on its conceptual classes and both of which have attempted to measure recall of specific semantic elements contained in a discourse.

The first line of work (Dawes, 1966) stems from Bartlett's (1932) studies of global aspects of subjects' recall of semantic information presented in a discourse (e.g. "conceptual complexity," "simplification," "structure"). Dawes was concerned with investigating Bartlett's hypothesis that as the retention interval between presentation of a passage and recall increases, the semantic structural information which is recalled will become simplified and at the same time will acquire greater structure. His method involved presenting an essay which was constructed to assert a number of set relations involving relations between certain conceptual classes. Dawes argued that the distortion of meaningful material which occurs in memory may be measured as transformations of the set relations contained in the presented material. The set relations which were considered by Dawes were nested relations (in which one set is entirely contained in the other or in the complement of the other): identity (all elements in two sets or conceptual classes are in common), exclusion (no elements are in common), and inclusion (all elements of one set are elements of the other); and disjunctive relations in which two classes have some elements in common but neither is included in the other. The measurements which Dawes obtained in his recall experiment were total number of relations recalled correctly, a simplification measure (number of "overgeneralized" relations, i.e. disjunctive relations recalled as nested minus number of "pseudodiscriminated" relations or nested relations remembered as disjunctive), an accuracy score (number of correct relations minus number of incorrect relations), and a simplicity score (number of correctly recalled nested relations minus number of correctly recalled disjunctive relations). Subjects recalled the relations asserted in the presented passage either immediately or after a two day retention period by listing all of the group relationships which they could remember. The "immediate" group was also tested after two days. Dawes' results indicated poor accuracy, and that simplification occurs, i.e. that distortions tend to yield simplification. He found no evidence to indicate that simplification increases with the passage of time.

The second line of work (Frase, 1969, 1972) is explicitly concerned with attempting "to understand how the relationships among the words that represent ideas in a text control and maintain conceptual processing, and consequently how they determine the knowledge that results from reading" (Frase, 1972, p. 338). Frase's approach involves attempting to manipulate specific processing operations by means of prior adjunct questions and then to study the effects of such "contexts" on the acquisition (recall) of specific elements (words) contained in the presented text. Thus, Frase (1969) presented subjects with essays containing five conceptual categories such that the classes formed a sequence in which adjacent pairs are connected by superset-subset relations. The subjects were told to read each passage and to find and underline the information which was needed to draw a conclusion typed at the top of each passage. A conclusion to be verified involved a stated superset-subset relation between two conceptual classes whose verification required the subject to scan from one to four intervening classes (as specified by the input sequence). Following this procedure, subjects were asked to write down everything they could remember from the passage. Studied were the effects of the questions upon the recall of each of the five conceptual categories. The basic assumption was that subjects would scan the passage for the information necessary to generate the transitive inference relevant to the to-be-verified conclusion and process only minimally information not relevant to the conclusion. Frase hypothesized further that text points irrelevant to the conclusion would be less likely to be stored in memory. Results were entirely consistent with Frase's hypotheses; recall of conceptual classes between concepts connected in a to-be-verified message was greater than for the remaining irrelevant concepts. This result was also found to be independent of sentence order. Frase's results are important for their convincing demonstration that both context-induced processing operations and semantic structural characteristics of a text can affect the acquisition (and recall) of specific conceptual elements contained in a text. Since Frase based his results on an extremely simplified semantic structure, it would be desirable to investigate similar effects with texts expressing a wide variety of semantic structures. Before any general conclusions are possible, it will be necessary to obtain such results based on more realistic semantic structures and to observe effects not only on recall of individual conceptual elements, but also on the acquisition of structural semantic information as well. Such studies could be most informative about the role of cognitive operations at the semantic level in the acquisition of semantic information from discourse.

The outlines of a research strategy for investigating the processes involved in acquiring semantic information from discourse should now be reasonable clear. It appears that if we are to progress in our knowledge of these processes, it will be necessary to have a method available for measuring precisely what semantic information is contained in a text and a method for measuring precisely what semantic information has been acquired from a text. If a semantic structural model of a text and an associated measurement procedure were available, then a research strategy could be adopted based on inferring the occurrence of specific processing operations in comprehension and semantic memory from: (1) measurements of specific semantic information in subjects' recall protocols: information which was acquired from the presented discourse, transformed in specific ways, or generated by the subject himself in specified manners from the input; and (2) observations of the effects of particular contextual conditions designed to induce particular processing operations on these measurements.

The present research has proceeded by first attempting to develop solutions to the twin problems of semantic representation of discourse and measurement of semantic information acquired from a discourse, and then attempting to apply the research strategy just outlined. The particular contextual conditions studied were designed both to induce certain inferential operations on text content and to relate to the notion that much of the "arbitrariness" which seems to be present in many laboratory comprehension tasks is due to the lack of specific context-defined goals to be attained in understanding and remembering information contained in a text. Thus, there may be an important difference between "reading" and "reading for a purpose," a difference which would appear to be likely to affect the types of heuristic procedures which subjects adopt in understanding and retaining semantic information contained in a text (cf. Freedle and Carroll, 1972). The three different task conditions adopted were designed to influence inferential operations on the input discourse, both quantitatively and qualitatively. The notion was that processes involved in acquiring semantic information from discourse would be dependent on operations on the semantic information to be performed after the information has been acquired. The experimental conditions used consisted of an "arbitrary" condition in which subjects were presented with a recorded discourse and then asked to write their reconstruction of the information which they had acquired from the discourse, a problem solving ("non-arbitrary") condition in which subjects were also required to generate for subsequent use as many different solutions as they could to a problem based on the content of the essay, and an incidental memory condition not requiring reconstruction of the input essay. Subjects in the first two groups wrote their recalls after each of four exposures to the discourse; subjects in the remaining group wrote their recalls only after the fourth exposure.

The research reported in the subsequent chapters was designed to obtain data relevant to a number of questions concerning those information processing operations which underlie the ability to acquire semantic information from discourse. Since these questions principally involve hypotheses about specific processing operations which occur and since the semantic analysis of subjects' recall protocols yields scores which appear to reflect the outcomes of specific classes of processing activities, we found it desirable to develop first in some detail a general process model for use as a theoretical framework within which specific questions could be formulated. The four specific issues which are described below constitute the principal questions to be investigated in Part I of this report.

1. Process invariance. There are two sorts of questions involving invariances which are of concern for a theory of natural language comprehension: structural invariance: "To what extent is the form of semantic information in long term memory resulting when a discourse is understood fixed or invariant?", and process invariance: "To what extent is the sequence of processing operations which generate this semantic information invariant?" Both sorts of invariance can be considered with respect to a variety of task characteristics such as surface and semantic properties of discourse inputs, temporal conditions, repeated exposures, and contextual conditions. The other side of these questions is concerned with the effects of such task characteristics on processing operations and semantic information resulting from these processes. The problem is to determine those aspects of processing which are under the control of discourse and task variables, and those aspects of the process which are relatively fixed or invariant. Studies of these questions will not only help identify specific processes which enable a person to extract semantic information from a discourse, but also will help to describe the manner in which these processes adjust to characteristics of an input discourse, repeated inputs, or discourse contexts. The present research will be concerned principally with process invariance, invariance with respect to the contextual conditions which have been described and with respect to repeated exposures to an input text.

2. Interpretive vs. generative processing. In Chapter 1, a distinction was made between a language processor which is "interpretive," i.e. capable of semantically interpreting linguistically coded input information, and one which is "generative," i.e. capable of generating new semantic information from linguistic inputs which are "semantically incomplete" (which incompletely code the semantic information which is necessary to understand the text).[2] A major question to be considered in the present research is: "To what extent do people process linguistic information generatively?" and "Can contextual conditions significantly influence the extent to which people process a discourse generatively?"

3. Role of generative processes. Suppose that the verbal recalls which subjects produce after being presented with a text contain relatively extensive semantic information which does not correspond to information which was explicitly represented in the input text. The presence of such subject-generated information implies that specific operations must have occurred to generate the information. An important question, given that generative processes occur, is to determine whether such processes occur as an input discourse is being processed, or whether a discourse is first processed interpretatively with generative operations (such as deductive inference, presupposition, certain kinds of retrieval) occurring subsequently--during output if the subject's recall is obtained immediately after the discourse is presented. It is clear that generative processing capabilities are

necessary, for example, to successfully interpret ambiguous constructions such as in ambiguous pronominal reference and syntactic ambiguity. The question being asked here is, "To what extent are generative processing capabilities involved beyond those minimally required to understand natural language texts?" A related question concerns the temporal locus of effects of contextual conditions on processing activities. Do the contextual conditions produce differences in the extent to which textual information is processed generatively _as it is received_, or do the conditions affect primarily the mode and extent of subsequent processing activities?

4. _Sources of individual differences_. A fourth kind of question is concerned with sources of individual differences in semantic information recalled or generated (and hence with differences in the sequence of information processing operations resulting in that information), and with effects of characteristics of discourses and contextual conditions on sources of individual differences. While studies of individual differences in language comprehension have tended to focus on outcomes, measuring differences in level of performance on various comprehension tasks, the approach to individual differences taken here focuses on both specific outcomes and on sources of individual differences in the particular sequence of processing operations which generate those outcomes. Thus, for example, it is of interest to know if individuals differ in the extent to which they process texts interpretively or generatively. Sources of individual differences may be investigated correlationally by obtaining measures of specific narrowly defined "abilities" and studying predictive relationships between these measures and measures obtained from scoring subjects' recall protocols. Analyses of effects of contextual conditions and effects of repeated exposure involve considering experimentally-induced differences in ability-response class intercorrelations. A rationale for this approach has been suggested earlier (Frederiksen, 1969) involving interpreting high correlations between a specific ability measure and response class as indicative of the particular process or processes involved in generating responses of that class.

CHAPTER 3

MEASUREMENT OF KNOWLEDGE ACQUIRED FROM A DISCOURSE

3.1 Introduction

The purpose of this chapter is to describe one procedure which has been developed for specifying a semantic structure for a connected logical discourse and for objectively measuring the semantic information which results from comprehension and memory processes. The procedure involves first, constructing a "semantic structural model" of an "input" passage, and second, scoring semantic or "ideational" features of a subject's written reconstruction of an input passage by fitting it to the "template" provided by the structural model of the input. This latter step involves the observation of a number of different types of response, each of which reflects different cognitive operations on the semantic structural features of the input. In developing a solution for the scoring problem (which might be described as a "template-matching" problem), it became increasingly obvious that any solution procedures inevitably would involve a conception of the processes involved in comprehending and remembering discourse. This chapter will begin with a description of some general considerations involved in choosing to represent a text structurally as a logical network. It will then present a description of the relatively undifferentiated structural model adopted in the first stage of this research, an application of this model to the analysis of the text used in the experiment whose results are described in Part I (Circle Island), and a description of the scoring procedures which are based on the model. The complete manual of instructions to scorers is found in Appendix A. Resulting from the semantic scoring of a subject's protocol are a large number of observations or measurements which can be pooled or classified in a number of ways. Certain of these response classes are of theoretical interest since they are likely to represent the outcomes of different processing operations. A number of response classes employed in the present research will be identified. The basic data will consist of the relative frequencies of occurrence of responses in each class. Theoretical interpretations of these classes of response will be presented in the next chapter. Finally, selected results obtained from an application of the scoring procedures to written protocols obtained from a sample of forty-seven subjects who listened to Circle Island and then attempted to reconstruct it will be presented.

3.2 Structural Representation of a Text as a Semantic Network

Suppose that a subject is presented with a connected passage which is sufficiently long that any complete reconstruction of the surface features of the passage is rendered extremely difficult. Suppose also that after hearing the passage read, the subject is asked to write down his reconstruction of the semantic content of the passage. The problem which confronts us is that of measuring or evaluating the extent to which the "meaning" of the input passage is preserved in the subject's written protocol. This problem obviously presents a number of difficulties, difficulties which upon reflection appear to center around the following two problems. First, define and represent the "meaning" of the passage given only its surface characteristics. Second, obtain objective and replicable measurements of the "correspondences" between the "meanings" of the passage and the "meanings" conveyed by the subject's protocol given a well-defined representation of the input passage but only the lexicographic surface structure of the subject's protocol.

The notion that the "semantic content" of a stimulus discourse might be represented structurally in the form of a directed graph (cf. Harary, Norman & Cartwright, 1955) has already been suggested by Dawes' (1966) experiments on the distortion of meaningful written materials in remembering, and Frase's (1969) demonstrations of the effects of thinking about particular relations between pairs of concepts contained in a passage on recall of elements taken from the passage. Dawes' work was based on a passage constructed mostly of simple declarative sentences expressing set relations and attempted to measure distorion in memory by reference to the set relations specified in the passage; Frase's experiments incorporated the idea that textual materials be represented in terms of networks of set relations which may be represented as directed graphs (cf., e.g., Harary, et al., 1965). Graph-structures also have been employed in computational linguistic work which attempts to represent the semantic content of English sentences in computer code (Simmons, 1972) and in computer models which attempt to simulate various results involving the semantic properties of lexical items as processes of retrieval from a semantic network (e.g., Quillian, 1968). Other work in linguistic semantics has employed various forms of predicate logic in representing propositions underlying English sentences. As Simmons has observed, "these forms are alternate representational conventions, and the choice of conventions for semantic representation need have no relation to the resulting power of the system" (1972, page 73). A major reason for choosing a graph representation in which concept-nodes are connected by directed line-segments (arrows) representing semantic relations is that it is easier to apply in representing discourses consisting of many sentences and in scoring semantic information acquired from a discourse. The predicate notation becomes unbearably difficult to read as the number of embedded predicate arguments and connected concepts increases. Also, as will be argued in Chapter 9, the fact that a predicate notation can be used does not mean that the propositions so represented "fit" nicely into any available system of predicate logic. Thus, in the present work, it was decided to enumerate set relations (of various defined types) and to represent these relations in networks of directed graphs. Any semantic network can be easily converted to a computer code by simply representing each relation as a function defined on concept pairs as arguments (cf. Simmons, 1972).

From the point of view of its function in communication, a discourse can be seen, first, as a means by which a speaker can specify a set of conceptual categories by means of a set of lexical designators and, second, as a means by which he can specify a set of semantic relationships which he asserts relate (connect) the specified conceptual categories. Thus a speaker can in general communicate conceptual and relational information by using a set of lexical designators (content words) which are assumed to be shared with the listener, to indicate or mark a set of conceptual categories; and by using shared rules of syntax, syntactic markers, and rules of expression to indicate or mark the relational information which connects the concepts. In addition, the speaker may assume shared knowledge about the world and shared ability to operate cognitively on that knowledge in deciding what conceptual and relational information to express (and what not to express directly). Comprehension, from this point of view, involves the listener's attempting to "infer" that conceptual and relational information which the speaker is attempting to communicate from the surface utterances of the speaker and given this shared knowledge. If this general conception of linguistic communication is correct, then the problem of representing the "meaning" underlying a discourse can have no purely formal or linguistic solution since in a sense the meaning underlying a discourse is the conceptual and relational information inside the speaker's head. For example, a speaker may use a lexical label to indicate a concept which he wishes to communicate, but the label may be imperfect as exemplified perhaps by later references to aspects of the concept not commonly associated with the lexical label. Or, a speaker may mark relational information connecting conceptual classes incompletely or ambiguously. It would appear, then, that the problem of specifying a semantic network underlying natural language discourse will have to be limited in a number of ways if it is to be made tractable.

One can, at this point, set different objectives for a structural representation of discourse. A stringent objective adopted by some computational linguists is to develop a method of semantic analysis (which may possibly be programmed on a computer) which is capable of "transforming strings of language into unambiguous relational structures of a cognitive model" (Simmons, 1968, page 1) with the ultimate objective of being able to generate English sentences from the model. A less stringent (and more pragmatically motivated) objective, is to develop a structural model which represents the "essential" conceptual and relational structure of a passage (as in "précis-writing") including some features which may not be explicitly expressed in the passage, but which is not necessarily capable of generating a surface structure identical to that of the original passage. A reasonable way to place limitations on the task of developing a semantic network representation of discourse when the stringent objective is adopted is to take the lexical elements (content words) as the concept-nodes in the graph structure and to make no attempt to analyze them further. These elements might, for example, be regarded as entry points to a long term memory structure in which information about lexical elements is stored. The "meaning" of a discourse in such an analysis consists entirely in this restricted case of the relational information which a discourse imposes on its lexical elements. This approach runs into a number of difficulties including a failure to account for the fact that conceptual information associated with a lexical element may be contextually dependent. Nevertheless, this approach to semantic analysis has been adopted in Part II of this report. Additional problems with such an approach to semantic analysis will be identified in Chapters 9 and 10.

The approach to be described in the present Chapter was to adopt an objective closer to the second less stringent alternative. Just what constitutes "essential logical features" is admittedly a somewhat subjective matter; we do not require that a structural representation be unique, only that it be logically consistent, well-defined,and capable of generating the essential semantic structure of the passage. Furthermore, it was felt that a representation satisfying the more stringent objective would most certainly come much closer to representing the surface characteristics of a discourse and would be likely to represent a fineness of meaning which may not be desirable if one's purpose is to describe and measure the conceptual and relational information which subjects acquire from a discourse. Finally, a more differentiated classification of types of relations and a more detailed analysis of conceptual elements can be made at a later time, even if the network itself does not so represent concepts and relations. For example, all that is needed to identify relation types not represented individually in the model is to list all examples of the types occurring in the model.

For the purpose of generating a representation of a text in terms of a network of set relations, in the present approach concept-classes are defined from which the relational structure of an essay can be generated. The concepts so-defined may be represented in the surface text as word groups (e.g., noun groups, verb groups, preposition groups, adjective groups, cf. Halliday, 1967, 1970; Winograd, 1972), as predicates, as embedded (relative) clauses, as certain unanalyzed comparative constructions, or as entire independent clauses. In the analysis of Circle Island (see Figures 3.1-3.8), a noun group which functions as the semantic subject of an independent clause was always taken as a single concept. In sentences containing no relative clauses, the predicate was taken as a single conceptual category. Sentences often were paraphrased, both systemmatically (e.g., as active sentences, with pronouns replaced by their antecedents, compound sentences broken up) and more freely by making lexical substitutions to simplify the semantic representation (e.g., "Circle Island has a shortage of water" changed to "Circle Island has little water") before conceptual categories were defined. Preposition groups specifying location were defined as conceptual elements, as were relative or comparative constructions (e.g., "north of Ronald Island" "Much more prosperous than the farmers"). Verbs were represented as concepts only when they had noun equivalents (e.g., export, government, decision) or when the remainder of the predicate contained an embedded clause (e.g., "pointed out that"). Thus, for example, the stative verb "want" was represented as a single concept followed by an embedded "goal" clause. Predicates represented as concepts assert such semantic relations as possession, attribution, class inclusion, affected object or person, and identity. Semantic subjects function as agents or instruments of an action, or as conceptual classes to be further differentiated by predicates asserting attribution, sub-classification, etc.[1] Predicates may also combine several of these semantic functions. Relative clauses were not analysed in the analysis of Circle Island

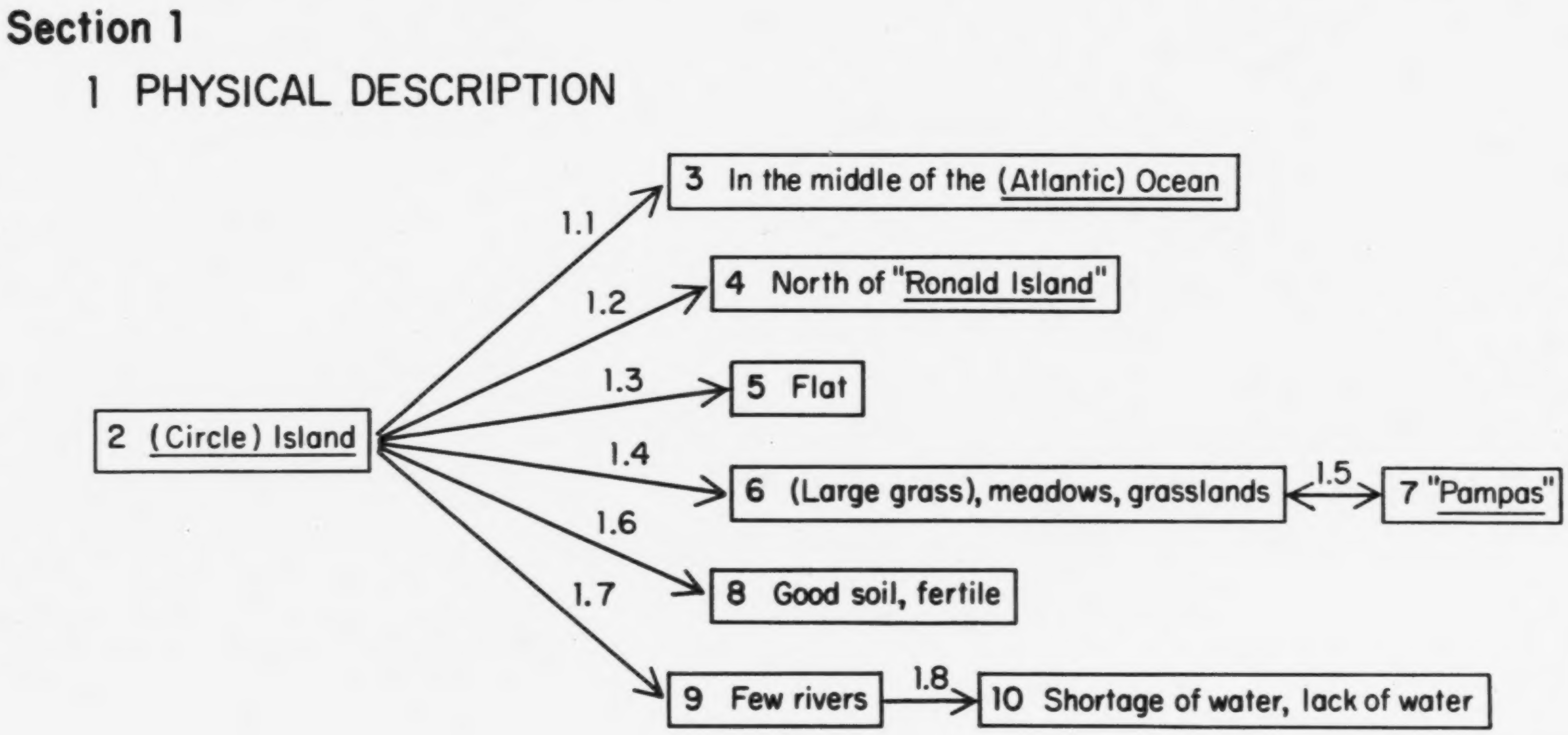

Section 1
1 PHYSICAL DESCRIPTION
2 (Circle) Island
1.1
3 In the middle of the (Atlantic) Ocean
1.2
4 North of "Ronald Island"
1.3
5 Flat
1.4
6 (Large grass), meadows, grasslands
1.5
7 "Pampas"
1.6
8 Good soil, fertile
1.7
9 Few rivers
1.8
10 Shortage of water, lack of water

Figure 3.1

Relational Structure: Circle Island, paragraph 1

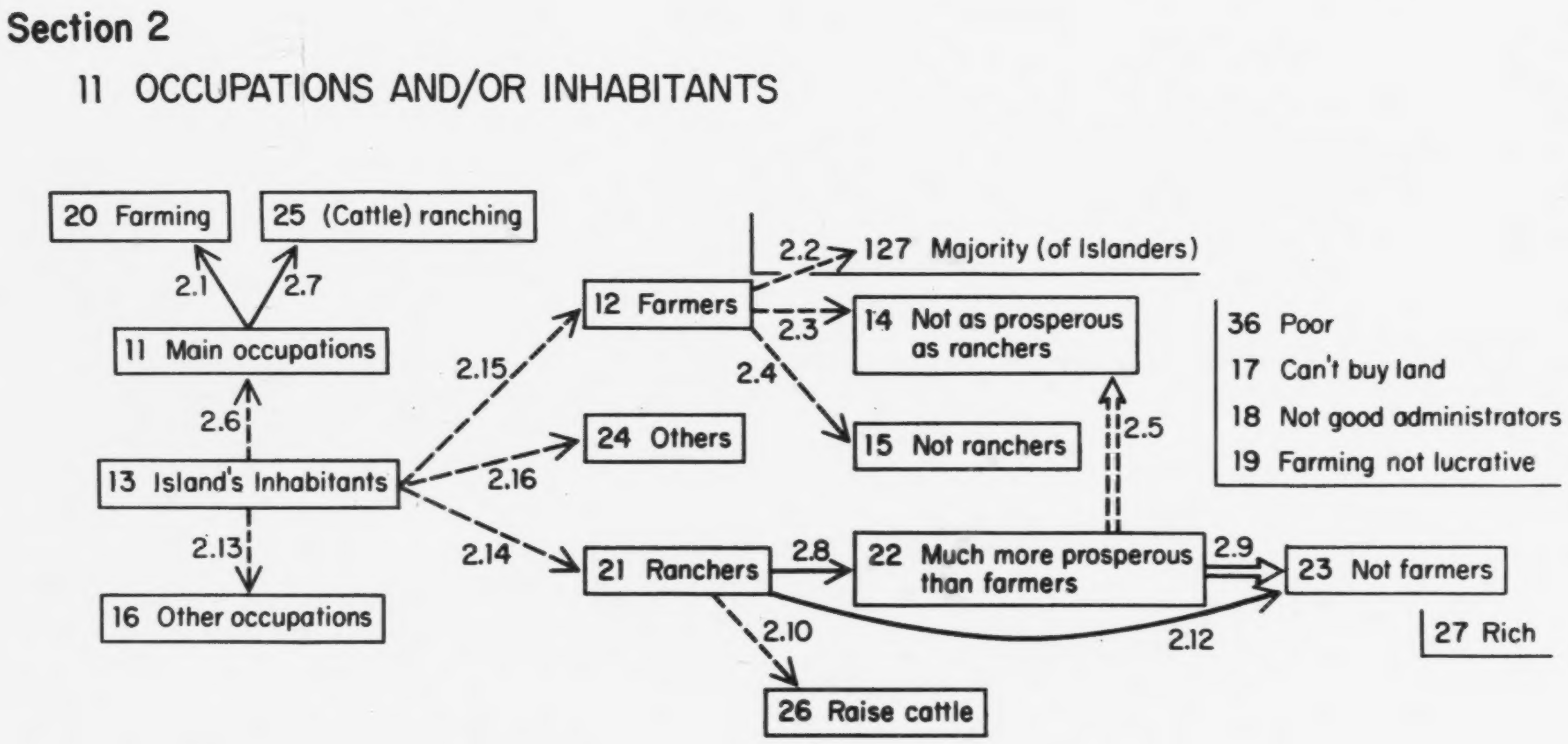

Section 2
11 OCCUPATIONS AND/OR INHABITANTS
20 Farming
25 (Cattle) ranching
2.1
2.7
11 Main occupations
2.6
13 Island's Inhabitants
2.13
16 Other occupations
2.15
2.16
2.14
12 Farmers
24 Others
21 Ranchers
2.2
127 Majority (of Islanders)
2.3
14 Not as prosperous as ranchers
2.4
15 Not ranchers
2.5
2.8
22 Much more prosperous than farmers
2.9
23 Not farmers
2.10
26 Raise cattle
2.12
36 Poor
17 Can't buy land
18 Not good administrators
19 Farming not lucrative
27 Rich

Figure 3.2

Relational Structure: Circle Island, paragraph 2(a)

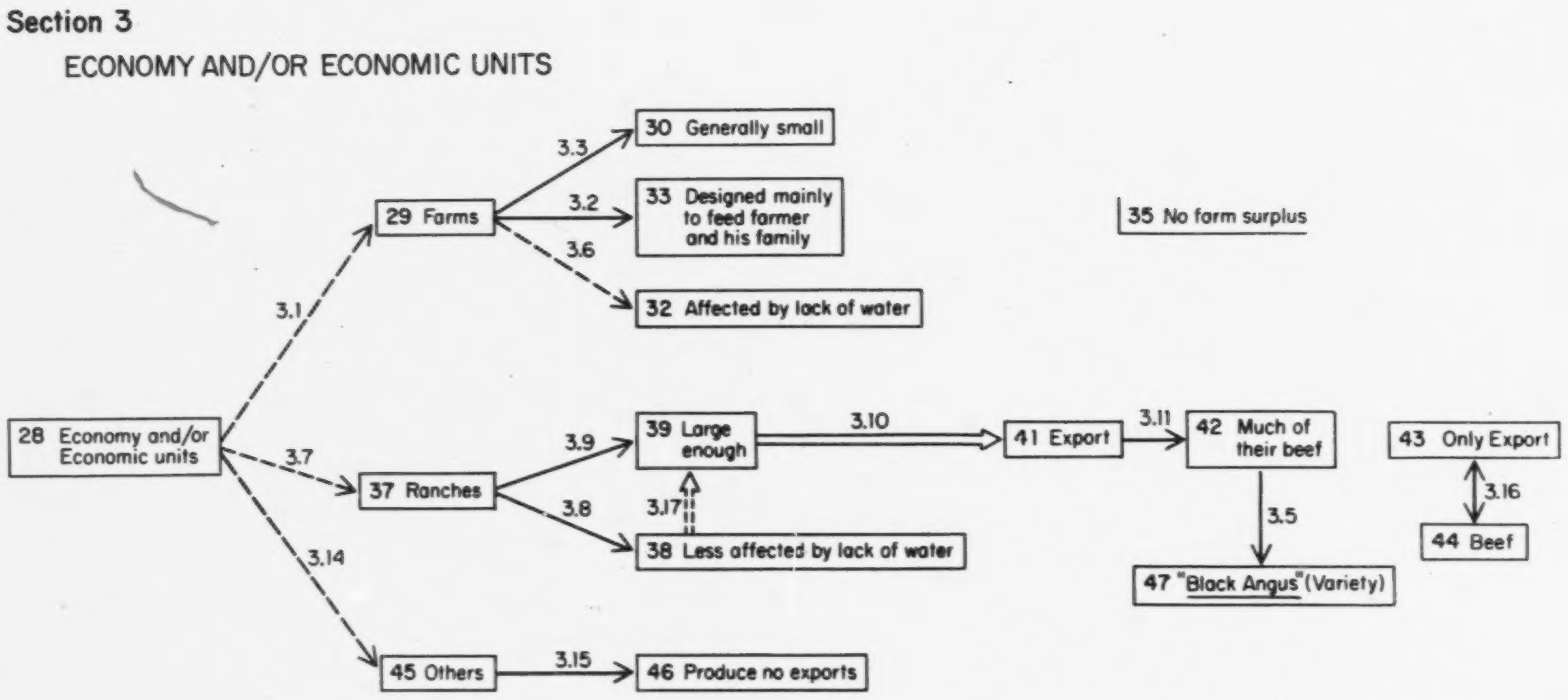

Section 3
ECONOMY AND/OR ECONOMIC UNITS
28 Economy and/or Economic units
3.1
3.7
3.14
29 Farms
3.3
3.2
3.6
30 Generally small
33 Designed mainly to feed farmer and his family
32 Affected by lack of water
35 No farm surplus
37 Ranches
3.9
3.8
39 Large enough
3.17
38 Less affected by lack of water
3.10
41 Export
3.11
42 Much of their beef
3.5
47 "Black Angus" (Variety)
43 Only Export
3.16
44 Beef
45 Others
3.15
46 Produce no exports

Figure 3.3

Relational Structure: Circle Island, paragraph 2(b)

Section 4

48 GOVERNMENT

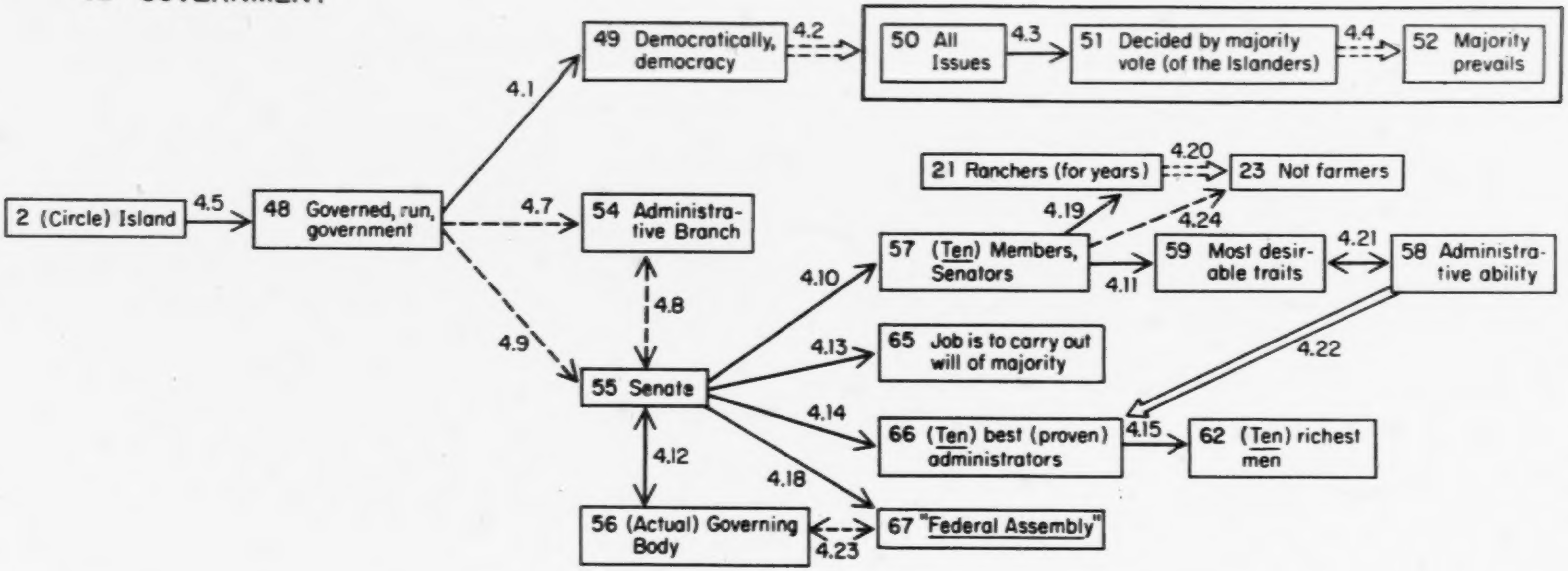

2 (Circle) Island
4.5
48 Governed, run, government
4.1
4.7
4.9
49 Democratically, democracy
4.2
50 All Issues
4.3
51 Decided by majority vote (of the Islanders)
4.4
52 Majority prevails
54 Administrative Branch
4.8
55 Senate
4.12
56 (Actual) Governing Body
4.23
67 "Federal Assembly"
4.10
4.13
4.14
4.18
57 (Ten) Members, Senators
65 Job is to carry out will of majority
66 (Ten) best (proven) administrators
4.15
62 (Ten) richest men
21 Ranchers (for years)
4.19
4.20
23 Not farmers
4.24
4.11
59 Most desirable traits
4.21
58 Administrative ability
4.22

Figure 3.4

Relational Structure: Circle Island, paragraph 3

Section 5A

POLITICAL EFFECTS OF CANAL PROPOSAL

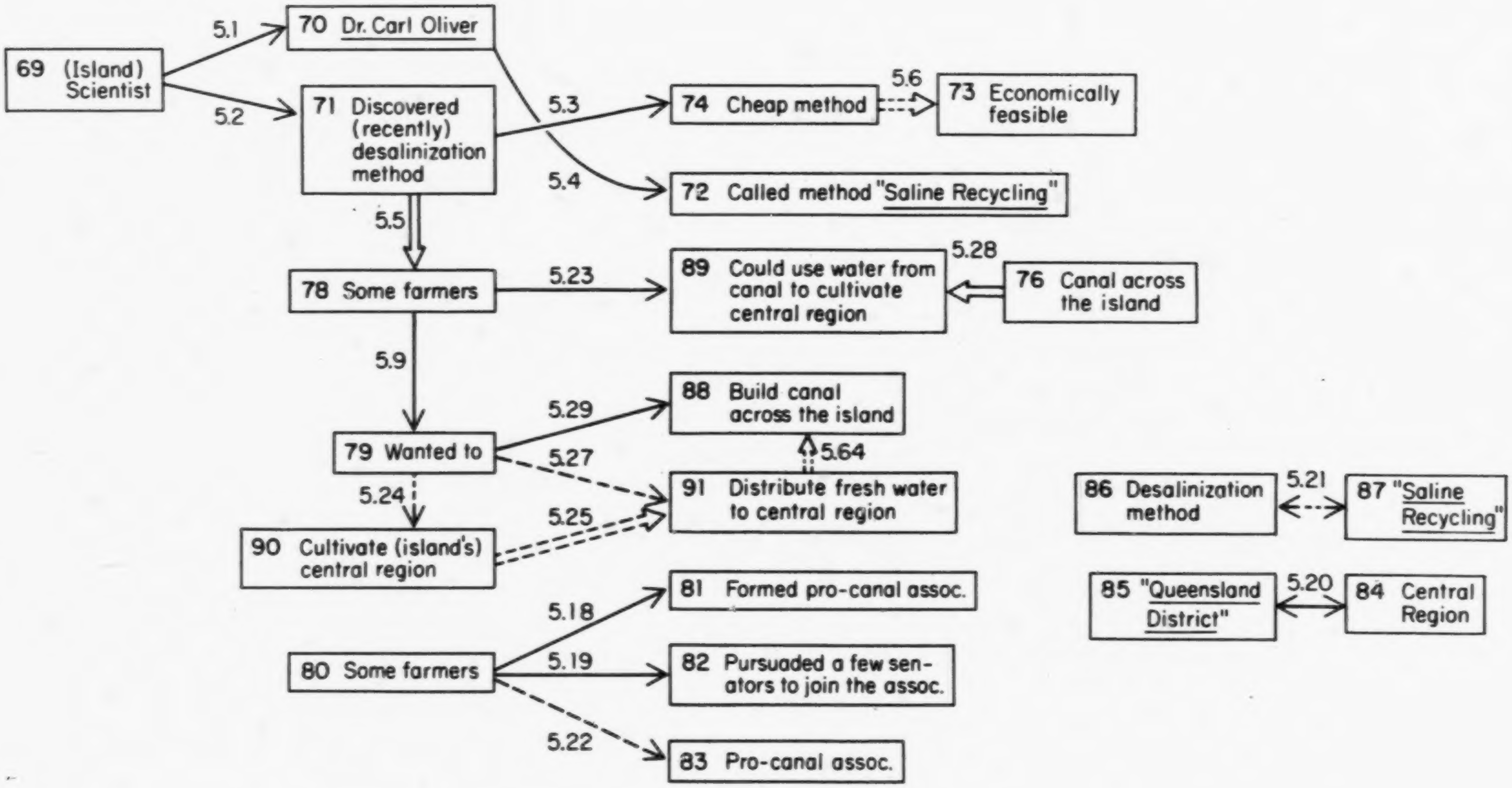

69 (Island) Scientist
5.1
70 Dr. Carl Oliver
5.2
71 Discovered (recently) desalinization method
5.3
74 Cheap method
5.6
73 Economically feasible
5.4
72 Called method "Saline Recycling"
5.5
78 Some farmers
5.23
89 Could use water from canal to cultivate central region
5.28
76 Canal across the island
5.9
79 Wanted to
5.29
88 Build canal across the island
5.64
5.27
91 Distribute fresh water to central region
5.24
5.25
90 Cultivate (island's) central region
80 Some farmers
5.18
81 Formed pro-canal assoc.
5.19
82 Pursuaded a few senators to join the assoc.
5.22
83 Pro-canal assoc.
86 Desalinization method
5.21
87 "Saline Recycling"
85 "Queensland District"
5.20
84 Central Region

Figure 3.5

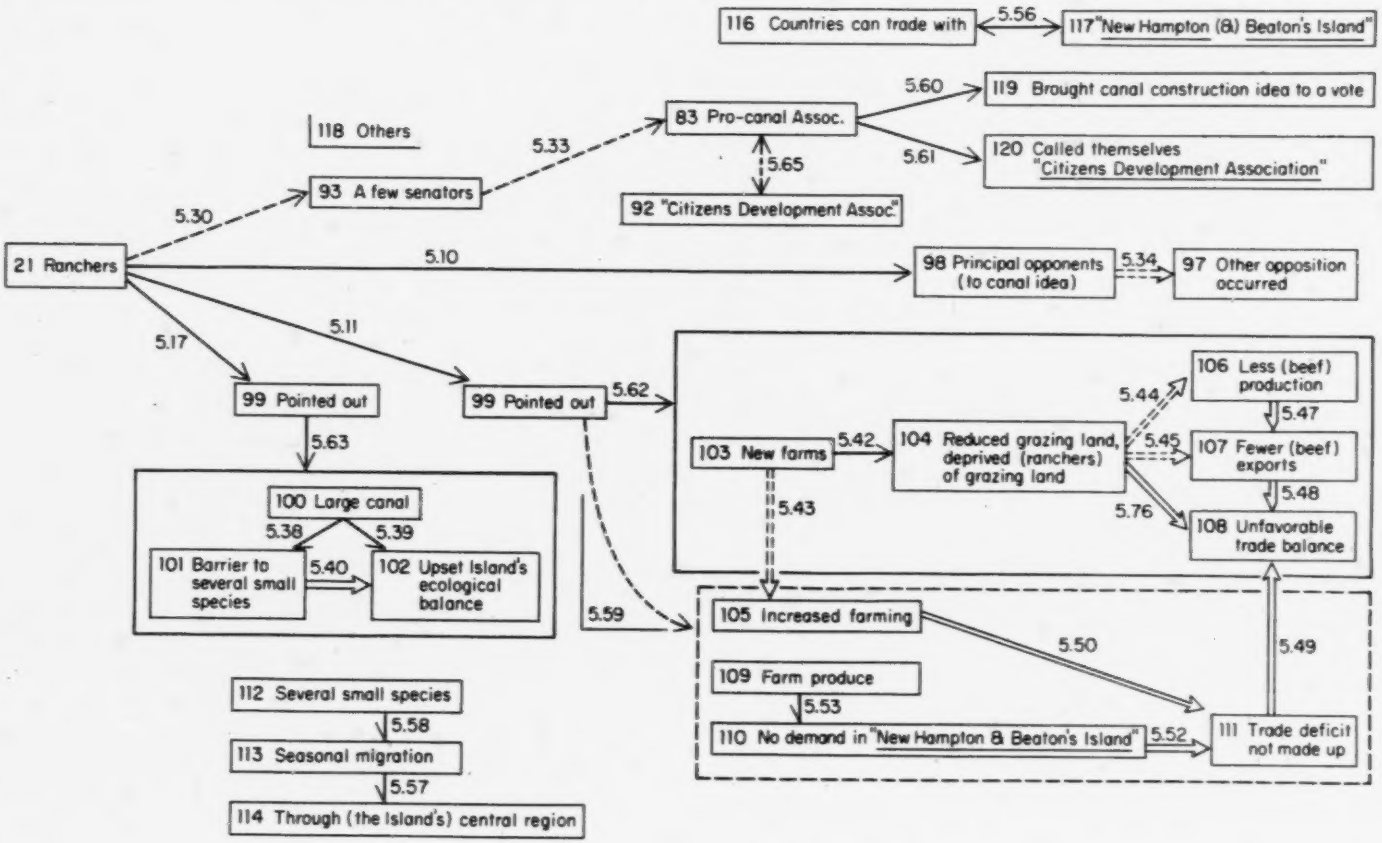
Relational Structure: Circle Island, paragraph 4

Figure 3.6

Relational Structure: Circle Island, paragraphs 5 and 6

Section 5B

98 MAIN OPPOSITION (TO CANAL IDEA)


116 Countries can trade with
5.56
117 "New Hampton (&) Beaton's Island"
118 Others
83 Pro-canal Assoc.
5.60
119 Brought canal construction idea to a vote
5.61
120 Called themselves "Citizens Development Association"
5.33
5.65
93 A few senators
92 "Citizens Development Assoc."
5.30
21 Ranchers
5.10
98 Principal opponents (to canal idea)
5.34
97 Other opposition occurred
5.17
5.11
99 Pointed out
99 Pointed out
5.62
5.63
106 Less (beef) production
5.44
5.47
103 New farms
5.42
104 Reduced grazing land, deprived (ranchers) of grazing land
5.45
107 Fewer (beef) exports
5.48
5.43
5.76
108 Unfavorable trade balance
100 Large canal
5.38
5.39
101 Barrier to several small species
5.40
102 Upset Island's ecological balance
5.59
105 Increased farming
5.50
5.49
109 Farm produce
5.53
110 No demand in "New Hampton & Beaton's Island"
5.52
111 Trade deficit not made up
112 Several small species
5.58
113 Seasonal migration
5.57
114 Through (the Island's) central region

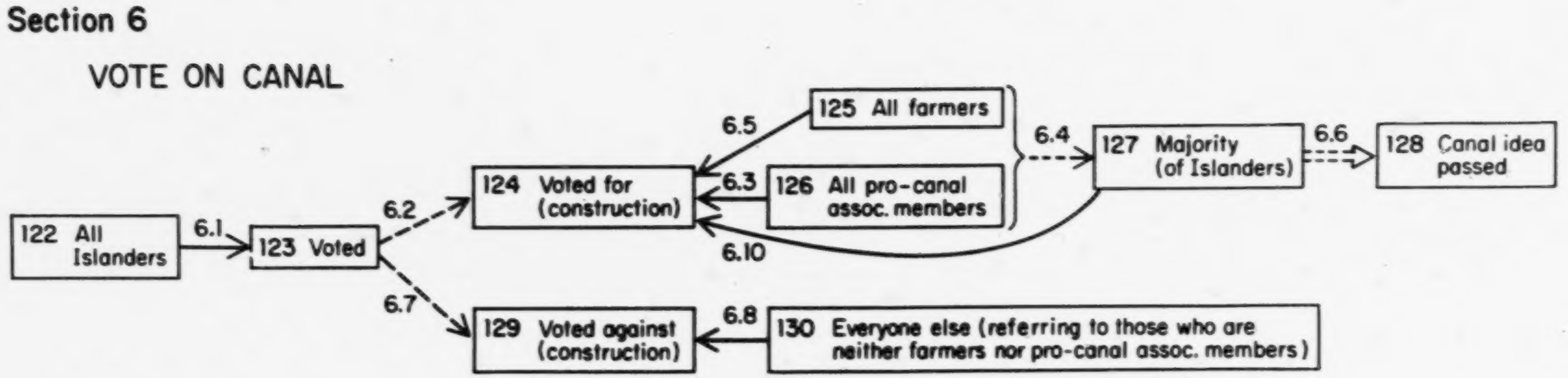

Section 6
VOTE ON CANAL
122 All Islanders
6.1
123 Voted
6.2
6.7
124 Voted for (construction)
129 Voted against (construction)
6.5
6.3
6.10
125 All farmers
126 All pro-canal assoc. members
6.4
127 Majority (of Islanders)
6.6
128 Canal idea passed
6.8
130 Everyone else (referring to those who are neither farmers nor pro-canal assoc. members)

Figure 3.7

Relational Structure: Circle Island, paragraph 7

Section 7

EFFECTS OF SENATE DECISION

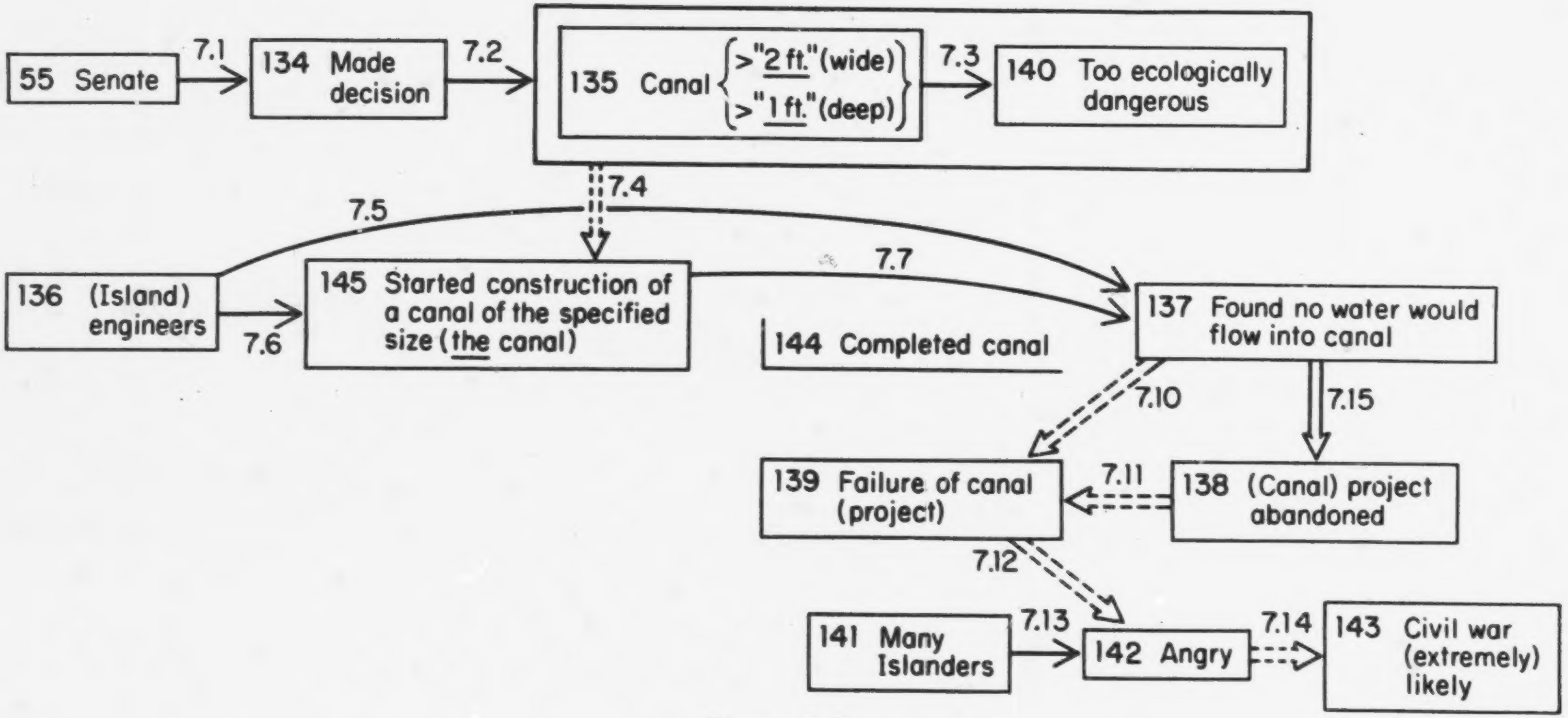

55 Senate
7.1
134 Made decision
7.2
135 Canal >"2 ft."(wide) >"1 ft."(deep)
7.3
140 Too ecologically dangerous
7.4
7.5
136 (Island) engineers
7.6
145 Started construction of a canal of the specified size (the canal)
7.7
144 Completed canal
137 Found no water would flow into canal
7.10
7.15
139 Failure of canal (project)
7.11
138 (Canal) project abandoned
7.12
141 Many Islanders
7.13
142 Angry
7.14
143 Civil war (extremely) likely

Figure 3.8

Relational Structure: Circle Island, paragraph 8

with one exception: relative clauses which represented a "theme" resulting from the action "pointed out" were analysed.[2] Thus, syntactic features of the passage were often used in the definition of concept classes. Unless concepts are identified with lexical items, some rather arbitrary decisions of this kind will probably be necessary for many textual materials. While most of the concepts defined in the manner just described can be further differentiated (i.e., themselves broken into set relations), it was felt that for the purpose of scoring conceptual and relational information acquired from a text, the concepts selected were sufficiently fine to represent many important set relations contained in the passage.

Once a set of conceptual categories has been defined for an essay, the graph structure may be specified by indicating with directed lines the relational links between concept pairs. The relational links designated are of four kinds. First, semantic relations are defined which differentiate concept sets by specifying new semantic information which is asserted to characterize or apply to the members of these sets. A semantic relation A ——> B is any directed relation which specifies either a state B of an object, being or, event A (such as location, time, attributes, possession, class membership, degree, and manner); or a relationship involved in an event (action), such as agency, instrumentality, object or being affected, goal of an action prior or resulting state, location, time, manner, and thematic content. These different functions of a relation are not differentiated in the graph structure. In the present model, a relation may represent more than one of the functions listed above. Second, bidirectional relations or identity relations are defined. An identity relation A <——> B asserts that two concept sets are identical and may be substituted one for the other. Any two concepts connected by a semantic relation or identity relation constitute a proposition. In the present analysis a proposition is always taken as asserted to be true.[3] The third kind of relation, the conditional relation, A ===> B, connects any two propositions and asserts that the truth of one proposition B is conditional on the truth of a second antecedent proposition A. Conditional relations include assertions of causal dependency, logical implication, or simple conditional dependency. A conditional relation can often be expressed as an "if . . . then" construction. In the graph structure, conditional relations are drawn connecting the terminal concepts of their respective propositions. The fourth kind of relation is the bidirectional conditional relation or bidirectional implication: "if and only if." This relation, denoted A <===> B, may be read "A implies and is implied by B" and does not occur in the *Circle Island* passage.

A diagrammatic model may be constructed from these concepts and relations linking concept sets which are represented as phrases in the diagram. "Represented in the model are concept-sets: in particular, (1) explicit concepts (concepts which are explicitly stated in the original passage); (2) certain inferred concepts (concepts which, while not stated directly, enter into relationships with explicit concepts which are necessarily true); (3) certain illustrative elaborative concepts (concepts which are not stated directly and do not enter into relations with explicit concepts which are necessarily true). Also represented in the model are set relations consisting of semantic relations and conditional relations, in particular; (4) explicit semantic relations; (5) explicit identities (bi-directional relations, A "is identical to" B); (6) explicit conditional relations (if A, then B, where A and B are propositions consisting of set relations); (7) explicit bi-directional implications (A "implies and is implied by" B); (8) inferred semantic relations and conditional relations (relations which, while not stated directly, are necessarily true within the context of the passage); (9) elaborative semantic relations; and (10)elaborative conditional relations. The decision was made not to represent separately different types of semantic relations and conditional relations, not to attempt any representation of qualifications (e.g., "may," "might"), and to represent instances of negation in terms of negative concept sets.[4] From the diagrammatic model, every concept and relation expressed in the original passage may be reconstructed. Each concept and relation in this diagram is identified by a code number which is used in scoring subjects' protocols by reference to the model. Such identification permits further classification of concepts, relations, and implications by listing. Note that it is not in general possible to represent in the model all implied relations and implications, expecially since such relations or implications can involve concepts not stated explicitly in the passage. This situation, a property of logical systems, necessitates certain complexities in scoring which will be discussed later.

The complete text of the essay Circle Island is presented in Appendix A. This essay was adapted from the essay used by Dawes (1966) and consists mostly of simple declarative sentences. The graph structure of the essay is presented in Figures 3.1 to 3.8. This graph structure is the template against which a subject's reconstruction of the essay is scored.

3.3 General Description of Scoring Procedures[5]

To obtain objective, replicable measures of the "degree of correspondence in meaning" between a subject's written protocol and the structure just described, one runs into certain complicating factors. In principle, a subject's protocol is itself analyzable logically and is representable in terms of a network. Thus, in principle, the scoring problem involves measuring the degree of correspondence of the two structures. In practice, this procedure is exceedingly difficult to objectify. The method which was adopted, attempts to make the structural analysis of subject's protocols objective by using the input structure as a model or "template" against which a subject's protocol is fit. The result is a structural representation of the subject's protocol based on its fit to the template. In most cases, this representation should be derivable from a structural model of the subject's protocol constructed by an independent logical analysis. To illustrate the sort of complexity one encounters in "template-matching," consider the following example. Suppose ARB is a relation present in the input (where R is a directed relation from concept A to concept B) and a relation A'R'B' be identified with a relation ARB contained in the model of the input, and given such identification, how might A'R'B' differ from the relation of the model with which it is identified? Consideration of this problem (which represents a relatively simple exemplar--complex cases involving, for example, embedding and nesting can occur) led to identification of certain possible subject transformations of an input triple ARB (see Figure 3.9). To provide a means for identifying a set relation in the subject's protocol with one in the model, the following condition was established. A set relation in a subject's protocol is identificable with a stated set relation in the input passage if the concepts and relations in the protocol may be transformed into those in the input passage by one of the transformations listed in Figure 3.9. The treatment of inferred set relations presents additional complexities, since it is not in general possible to enumerate all possible relations inferrable from the model, especially those involving subject-generated concepts.

The treatment of these and other scoring problems involves a consideration of the protocol produced by a subject as the result of a sequence of processing operations and relations between ARB and A'R'B' (exemplar) ought to be describable in terms of classes of responses resulting from the application of particular processing operations. A description of a model characterizing these processes will be presented in the next chapter. Of particular interest in the present context, is a classification of certain processes in comprehension and memory for connected discourse (see Figure 3.10), since these provide a rationale for the scoring procedures to be described. According to this conception, comprehension involves the construction of a logico-semantic model of an input passage. Four sorts of process are identified: selection processes (e.g., selection of an element of the input string for further processing, generative processes (e.g., encoding, generation of an element of a semantic model), and verification processes (establishment of a correspondence between an element generated and an element input), and transformation (operation on the generated semantic model to change its conceptual and relational structure. The classes of processes identified in Figure 3.10 correspond rather directly to classes of scores obtained in matching a subject's protocol to the template. For example, verification of identity by the subject yields a concept in the subject's protocol which is identical to one in the input. Verification of class correspondence yields a concept which may be over-specified (concept-set overly delimited, i.e., representing a subset of the concept-set of the input) or incompletely specified (concept-set not completely delimited, i.e., includes subsets not corresponding to the concept-set of the input), and verification of implication yields a concept which does not correspond to any concept of the input, but which enters into derivable relations with concepts of the input. Note that these types of verification each determine a particular unique correspondence between an element produced (encoded and subsequently reproduced) by the subject and an element of the input. Note also that a similar classification may be made for more complex elements present in subject's protocols such as relations, implications, or structures (systems of relations). Having briefly indicated the rationale for our scoring system, the description of our procedures for "template-matching" can be concluded.

A,B are input concepts

A,B may be explicit or inferred

R is an input relation

R may be:	explicit	inferred
1. Semantic Relation	———>	- - - ->
2. Identity Relation	<———>	<- - - ->
3. Conditional Relation	════>	= = = =>
4. Bi-directional Implication	<════>	<= = = =>

MODEL: ARB

PROTOCOL: A'R'B'

POSSIBLE SUBJECT TRANSFORMATIONS ON:

CONCEPTS	RELATIONS
A' = A [no transformation]	R' = R [no transformation]
A' = A+ [incompletely specified]	R' = M(R) [mode transformation]
A' = A- (overspecified)	R' = D(R) [direction transformation]
A' = ∅ [null transformation]	R' = I(R) [identity transformation]
The same transformations may be applied to concept-set B.	R' = M*D(R) [mode and direction]
	R' = M*I(R) [mode and identity]

Figure 3.9. Summary of symbols used in representing connected discourse as directed graphs consisting of networks of set relations, and of possible subject transformations.

A. ELEMENTS OF SEMANTIC MODEL

1. Concepts (Classes)
2. Relations (Simple, compound, nested)
3. Implications (Simple, compound, nested)
4. Structures (Systems of relations, implications)

B. PROCESSES

1. Selection	Surface (Non-criterial)
	Inferential (Criterial)
2. Generative Operations	Interpretive (Encoding)
	Inferential
	Elaborative
	Null
3. Verification	Simple Identity
	Class Correspondence
	Implication
	Non-Contradiction
	Null
4. Transformation	

Figure 3.10

Classification of possible elements of semantic model and processes in comprehension, memory, and reconstruction of connected logical discourse.

The semantic scoring of subjects' protocols against the constructed model of the input passage involves three steps: verbatim scoring, concept scoring, and relations scoring. Verbatim scoring of a protocol involves reading the protocol and underlining every item of a fourteen item list of verbatim concepts, each of which occurs in the input passage. Each verbatim concept is scored as either: correct (verbatim criterion); incompletely specified (if a portion of the verbatim concept appears); or absent. Total verbatim elements correct and incomplete are obtained. These totals are the basic verbatim data and are obtained for each subject for each trial.

Concept scoring involves underlining and scoring each of a list of concepts which appear in the original passage and which are numbered and diagrammed in the model. The scoring sheets contain a list of numbered concepts section-by-section. Each concept is scored as correct, incompletely specified, or over-specified. These scores may be thought of as transformations of the input concept by the subject. Concepts appearing in a subject's protocol are classified as explicit, inferred, or elaborative and are so identified on the scoring sheet. An additional scoring sheet is provided for listing all (subject-generated) inferred and elaborative concepts which do not appear on the previous sheets. Each concept which is explicit is scored as correct, incompletely specified, over-specified, or absent; each inferred or elaborative concept is scored as present (meaning subject-produced). Totals for each concept type and scoring category are obtained for each section (the sections correspond to serially located paragraphs in the input passage) and for each trial. This procedure yields a rather large number of scores which represent amount of information, accuracy of information, and transformations on information in the input. Difficult scoring situations sometimes occur involving such aspects as: stating conditions distinguishing situations in which the "over-specified" score category is used vs. scoring the concept and the additional words as an additional (subject-produced) inferred or elaborative concept; and stating conditions for the substitutability of identities and the treatment of embedded verbatim concepts (verbatim concepts which are embedded in other concepts). (See Appendix A, section 10).

Set relations scoring is considerably more complicated than concept scoring and, like the concept scoring, involves scoring a subject's protocol against the structural model of the original passage. As in the concept scoring, set relation scoring consists of categorizing a set relation in a subject's protocol in terms of transformations on a set relation in the model with which the set relation in the protocol is identified. A set relation in a subject's protocol is identifiable with a stated set relation in the input if the relation appearing in the protocol may be transformed into that in the input passage by one of six possible transformation (see Figure 3.9). Possible transformations on a relation R are: no transformation; transformation of mode (relation to implication and vice versa); of direction (for unidirectional relations or implications); to or from an 'identity' (i.e., a unidirectional relation may become bi-directional, and vice versa); mode and direction; and mode and "identity." Four possible transformations on a concept are: no transformations, incomplete specification of the concept-set, over-specification of the concept-set, or deletion. Each triple consisting of two concepts and a connecting set-relation, which appears in a subject's protocol and is identifiable with a set relation in the input passage, then represents one of 96 possible score patterns. In addition, set relations may be explicit, inferred, or elaborative. An elaborative relation is not scored "transformationally," but only as to whether or not it contradicts the semantic content of the passage. The scoring sheet for each protocol contains a list of numbered relations (as rows) and three columns headed R', A', and B'. In columns A' and B' the appropriate transformations on A and B (corresponding to the numbered relation in the model) are recorded as previously obtained in the concept scoring. Then a judgment is made as to what transformation has been applied to R and this transformation is recorded. To illustrate some of the complexities which can occur in scoring relations and implications, two sorts of problems for which detailed scoring rules are necessary may be mentioned. The first involves the scoring of conditional relations involving compound concepts. The scoring procedure involves rules for breaking such relations into parts, or, if this is not allowed under the rules, for scoring the transformation on the compound concept (see Appendix A, section 12). The second complexity involves the treatment of nested relations. As an example of the kind of scoring rule adopted to handle such complexities, see Appendix A, section 12, "Nested Relations."

A sample of a subject's protocol is provided in Figure 3.11; this protocol has been scored and the coded scored protocol is given in Figure 3.12. Since virtually every concept and set relation produced by a subject in his protocol is scored and recorded, a tremendous variety of classes of responses may be obtained by counting frequencies of occurrences of given response types. For example, for explicit relations there are 54 = 3 x 3 x 6 possible score patterns. If concepts or relations are further differentiated, then the number of possible score patterns for a triple consisting of two concepts and a relation increases by multiples. Certain classes of responses are identifiable as the results of processing operations specified in the model for comprehension-memory-reconstruction processes which was described earlier. A list of response classes obtained from frequency counts of various pooled semantic scores and corresponding to performances resulting from specific comprehension and memory processes is found in Figure 3.13. These score classes may represent rather direct measurements of the operation of specific processes in comprehension and memory.

3.4 Results

The passage in Appendix A was presented to 47 subjects by means of a tape recorder. All subjects were undergraduates at California State College at Hayward and there were 18 males and 29 females in the sample. Subjects were told that the material which they would hear would consist of a passage which describes a socio-political problem on an hypothetical island, involving a canal, a threatened civil war, and the probable collapse of the island's economy, and were asked to

Figure 3.11

Reproduction of a Scored Protocol

```
CONDITION   SUBJECT   SEX
              0405      1    1021R111
                 1001C143
CIRCLE ISLAND IS A SMALL ISLAND NORTH OF RONALD ISLAND/  ITS INHABITANTS
            2                **        4              V                13

ARE EMPLOYED IN RANCHING AND FARMING/  THERE IS NOT MUCH WATER AVAILABLE/
          11+            25         20                                 10

SO THE FARMS ARE SMALL/  THE RANCHERS (WHO RAISE BLACK ANGUS CATTLE HAVE
           29         30-             21        26            47

LARGE ENOUGH RANCHES SO THAT THEY MAY EXPORT SOME CATTLE/  THE ISLAND IS
           39      37                      41          42+           2

GOVERNED BY A SENATE (COMPOSED OF THE TEN BEST PROVEN ADMINISTRATORS THE
       48          55                  V                            66

TEN RICHEST MEN/  ALL OF THESE MEN ARE RANCHERS/  A SCIENTIST PROFESSOR
              62                 57          21             67        **

OLIVER RECENTLY DISCOVERED A CHEAP WAY TO CONVERT SALT WATER TO FRESH
   +                     71     74

WATER AND CALLED IT SALINE RECYCLING/  THE FARMERS WANTED TO TAKE ADVANTAGE
                                V  72            78+        79            *

OF THIS PROCESS BY BUILDING A CANAL ACROSS THE ISLAND/  THEY FORMED A
                                                    88             81

GROUP OF FARMERS CALLED THE PROCANAL GROUP/  THE RANCHERS OPPOSED THIS
                                                       21          98+

IDEA BECAUSE THEY SAID IT WAS ECOLOGICALLY UNSOUND/  THE PROPOSAL WAS PUT
                     99                         102+

TO A VOTE/  AND THE PROCANAL GROUP WON/  THE SENATE THOUGH WOULD ONLY ALLOW
       119                           *          55                     134

A CHANNEL TWO FEET WIDE AND ONE FOOT DEEP TO BE BUILT/  THE CANAL WAS BUILT/
       135            V                V                                144

BUT ENGINEERS FOUND (THAT NO WATER WOULD FLOW INTO THE CHANNEL/  THE PROCANAL
          136                                                137

GROUP WAS UPSET AT THIS/  AND CIVIL WAR NOW THREATENS THE ISLAND/
   83        142+                                              143

END OF PROTOCOL 1 FOR THIS SUBJECT
```

Figure 3.12*

Relations and Implications from Scored Protocol

(as coded for the computer)

Identification	Scores							
01 1 0405 1*	1021R111**	2011R211	2061R422	2071R211	2101R142	3031R131	3091R111	3111R121
02 1 0405 1	3103R121	4051R111	4091R112	4141R111	4152R111	4191R111	5012R121	5021R111
03 1 0405 1	5031R111	5041R111	5091R211	5291R111	5101R121	5171R111	7011R111	7021R131
04 1 0405 1	7051R111	1001R143	2001R412	3001R112	5002R412	5001C213	9001R122	9001R122
99 1 0405 1	7001C123	3003R132	9003R222					

---

*Identification:	01	1	0405	1		
	Card No.	Condition	Subject	Trial		
	102	1	R	2	1	1
**Scores:	relation no.	relation or implication bi-directional or uni-directional	R'	A'	B'	type

*See Figure 3.11 for examples of the scores underlined above; "relation" = semantic relation "implication" = conditional relation

I. DISCRIMINATION
   A. Concepts
      1. veridical (A)
      2. overgeneralization (A+)
      3. pseudodiscrimination (A-)
   B. Semantic Relations
      1. veridical ARB
      2. overgeneralization
         A+RB, ARB+, A+RB+, A-RB+, A+RB-
      3. pseudodiscrimination
         A-RB, ARB-, A-RB-
   C. Conditional Relations
      1. ARB
      2. overgeneralization
         A+RB, ARB+, A+RB+, A-RB+, A+RB-
      3. pseudodiscrimination
         A-RB, ARB-, A-RB-

II. INFERENTIAL PRODUCTION
   A. Concepts
      1. inferred concepts
   B. Semantic Relations
      1. inferred semantic relations among explicit concepts
      2. inferred semantic relations among inferred concepts
      3. inferred semantic relations including inferred concepts
   C. Conditional Relations
      1. inferred conditional relations among explicit propositions
      2. inferred conditional relations among inferred propositions
      3. inferred conditional relations including inferred propositions

III. ELABORATIVE PRODUCTION
   A. Concepts
      1. elaborative concepts
   B. Semantic Relations
      1. elaborative semantic relations which are not false
   C. Conditional Relations
      1. elaboratove conditional relations which are not false

IV. TRANSFORMATION
   A. Semantic Relations
      1. transformations on R where R is a semantic relation
      2. false subject-produced semantic relations
   B. Conditional Relations
      1. transformations on R where R is a conditional relation
      2. false subject-produced conditional relations

Figure 3.13

Classes of responses in reconstructed logical discourse.

recount in writing what they had heard. They were also told not to attempt to write a verbatim reproduction of the passage. Subjects heard the passage four times, writing their reconstructions of it immediately after each exposure. One week later, the subjects returned to take a number of ability tests, and, at this time, a fifth reconstruction of the passage was obtained.

Three sorts of results based on these data will be described in this chapter: results concerning inter-scorer reliabilities, results concerning mean response-class frequencies for particular classes of structural elements (concepts, relations, implications), and multi-occasion intercorrelations of certain response class frequencies. Consider first the results concerning inter-scorer reliabilities summarized in Table 3.1. The response classes studied correspond to response classes identified in Figure 3.13. Inter-scorer reliabilities were estimated conservatively by double scoring the first and third trials of fourteen protocols. The second scorer's experience consisted only of a reading of the scoring manual, and a short training session; the scorer was familiar with the general nature of the research. To increase response class frequencies for purposes of estimating inter-scorer reliability, scores on the two trials were pooled for each protocol. The results indicate rather good agreement among scorers for response classes having relatively high frequencies. It is interesting that the inter-scorer reliability for veridical relations is about as high as for complete verbatim concepts, since the former score represents a scoring judgment which is far more complex than the latter. Note that not every response class of Figure 3.13 has been analyzed; some scores were inadvertently omitted from our analyses. The data for inferred and elaborative relations suggest that the scoring decisions associated with this distinction may be made more objective. The difficulty appears to involve deciding whether or not relations involving subject-produced concepts are implied by relations present in the passage. This appears to have been one of the most difficult scoring decisions.[6] The general picture of these results concerning inter-scorer agreement appears to be quite promising, a result which is rather remarkable given the complexity of the scoring task. Objectivity appears to have been achieved to a large measure by the specification of very detailed decision rules for difficult scoring situations.

Mean response-class frequencies for each trial are plotted in Figure 3.14 for a number of classes of structural elements varying in complexity from concepts, to semantic relations, to conditional relations. A number of observations are suggested by these plots.

1. Consider the center graph, trial 1. It is striking to note that the frequencies of overgeneralized and inferred relations are about as great as that for veridical relations. Thus, for long passages given only one hearing, it would appear that verification of class correspondence or implication is about as likely as simple verification of identity. This result suggests that inferential processes are an integral part of comprehension, especially for long passages in which encoding of surface features is difficult. When this result is compared

Table 3.1

Mean Absolute Frequencies of Various Response
Classes, Standard Deviations, and Interscorer Reliabilities

Response Class	Mean Absolute Frequencies		Standard Deviation		Estimated Interscorer Reliability
	(1)	(2)	(1)	(2)	
Discrimination:					
1. Veridical concepts	49.50	48.86	11.43	10.54	.892
2. Overgeneralized (incomplete)concepts	14.79	16.21	5.85	5.06	.687
3. Pseudodiscriminated (over-specified) concepts	6.64	6.93	2.97	4.01	.611
4. Veridical relations	21.50	22.57	7.12	7.76	.940
5. Overgeneralized semantic relations	11.86	11.21	4.72	4.75	.692
6. Pseudodiscriminated semantic relations	4.14	4.86	3.09	3.08	.688
Inferential Production:					
7. Inferred semantic relations	14.64	16.71	5.18	5.51	.537
8. Inferred conditional relations	3.43	3.79	2.06	2.46	.343
Elaborative production:					
9. Elaborative concepts	14.64	9.93	5.79	3.39	.858
10. Elaborative semantic relations*	10.43	7.21	5.17	3.75	.656
11. Elaborative conditional relations**	3.64	3.29	1.88	1.91	.588
TTransformations:					
12. Transformed semantic relations	2.79	3.29	1.61	2.43	.489
13. Transformed conditional relations	.50	.57	.63	.90	- ***
Verbatim:					
14. Complete verbatim concepts	13.71	13.36	4.54	4.40	.980
15. Incomplete verbatim concepts	2.50	2.50	.91	1.18	.701

*includes false subject-produced semantic relations and thus involves transformations.
** includes false subject-produced conditional relations
*** insufficient frequency to estimate

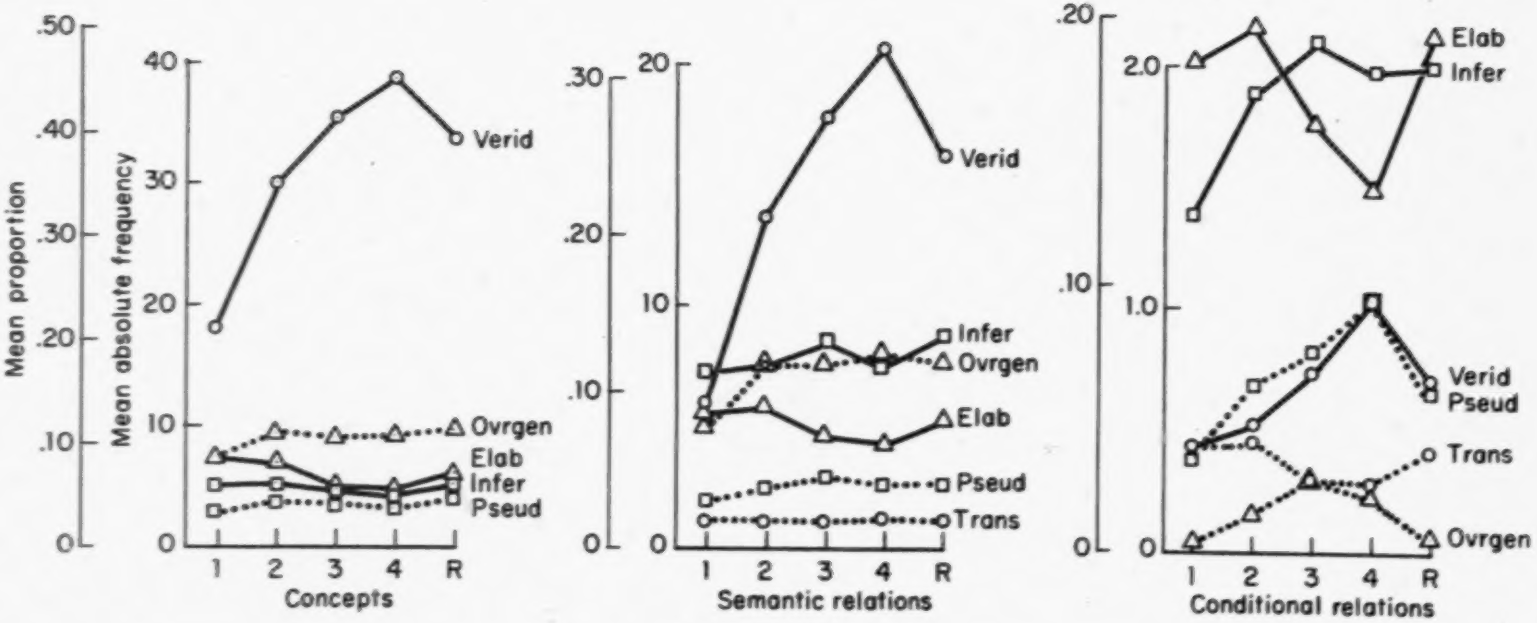


Figure 3.14

Mean Response Class Frequencies for Concepts, Semantic Relations, and Conditional Relations to the result (on trial 1) for conceptual-elements, it appears as if the result occurs only for the more complex structural elements (the relational structure). This result appears to provide a rather powerful argument for obtaining a structural representation of the semantic content of a subject's protocol.

2. There appears to be a rather large increase in the extent of identity verification and hence (interpretive) generative operations (or encoding) with repeated exposure to the passage, an increase which is reflected in the change in frequencies of veridical concepts and relations over trials.

3. There is an increasing proportion of inferred and elaborative elements relative to veridical elements as the elements become more complex, i.e. from concepts to semantic relations connecting concepts, to conditional relations connecting propositions.

4. The frequencies of various response-classes involving conditional relations are very low, a result which is certainly due to the relatively low rate of occurrence of conditional relations in the input passage. A passage containing well-developed, conditional dependences would have to be used to study processing of conditional relations. Such a passage will be used in Part II.

5. Transformations also occur infrequently. Any detailed investigation of transformations will certainly have to make their occurrence more frequent. In addition, a more detailed classification of transformations based on a more detailed semantic model would be desirable. For example, an important transformation which may occur with greater frequency is that involving confusion of causal and logical conditional relations. In fact, these two cases were pooled in the present scoring procedures.

6. Finally, there is a suggestion of an increase in elaborative and inferential production in reminiscence and a definite decrease in "simple" production (frequency of veridical elements present).

Multi-occasion correlations of response class frequencies based on veridical, overgeneralized, pseudo-discriminated, inferred, and elaborative semantic relations are presented in Table 3.2 (fifteen measures are correlated and so the table has three parts). In examining this Table, we will consider separately the 5 x 5 within response-class correlation sub-matrices along the diagonal and the between response-class correlations which constitute the remaining parts of the matrix. In Chapter 6 procedures for fitting mathematical models to this matrix to investigate hypotheses concerning its structure will be described. Consider first the intercorrelations of frequencies of veridical semantic relations across the four trials and reminiscence trial. A simplex pattern of correlations, greater for adjacent trials and least for trials farthest removed, may be seen to occur for the first four trials. Such a pattern is common for longitudinal growth data and for measures which change stochastically over occasions. Note that the level of within response-class correlation is relatively high within the constraint of the simplex structure.

Table 3.2(a)

Multi-Occasion Intercorrelations of Response Class Frequencies Based on Veridical, Overgeneralized Pseudodiscriminated, Inferred, and Elaborative Semantic Relations

	V.1	V.2	V.3	V.4	V.5	0.1	0.1	0.3	0.4	0.5	P.1	P.2	P.3	P.4	P.5
Veridical															
Trial 1	-														
Trial 2	.642	-													
Trial 3	.433	.799	-												
Trial 4	.469	.717	.864	-											
Trial 5	.441	.712	.833	.761	-										
Overgeneralized															
Trial 1	.551	.595	.549	.531	.443	-									
Trial 2	.108	.093	.207	.233	.163	.345	-								
Trial 3	.049	.199	.313	.441	.208	.344	.604	-							
Trial 4	-.106	.009	.137	.054	.115	.147	.222	.371	-						
Trial 5	-.017	.364	.510	.456	.371	.236	.197	.455	.327	-					
Pseudodiscriminated															
Trial 1	.281	.352	.189	.050	.101	.268	.228	.022	.026	-.225	-				
Trial 2	.043	.196	.248	.178	.233	.195	-.074	.115	.345	.121	.283	-			
Trial 3	.204	.266	.202	.182	.237	.318	.083	.032	-.035	.091	.184	.380	-		
Trial 4	-.234	-.084	-.192	-.216	-.078	-.136	-.043	.006	.046	.001	-.062	-.008	.137	-	
Trial 5	-.030	.213	.222	.108	.151	.211	.114	.172	.274	.199	.076	.311	.297	.234	-

Table 3.2(b)

	V.1	V.2	V.3	V.4	V.5	0.1	0.2	0.3	0.4	0.5	P.1	P.2	P.3	P.4	P.5
Inferred															
Trial 1	.062	.306	.241	.143	.257	.295	-.088	-.046	.173	.044	.395	.207	.026	-.125	-.038
Trial 2	-.214	.042	.027	.017	.046	-.022	.089	-.109	-.124	.034	.038	-.111	-.183	-.105	-.259
Trial 3	-.125	.156	.066	.066	.068	.092	.086	.026	.106	.294	-.037	.268	-.056	-.018	.003
Trial 4	-.362	-.114	-.113	-.097	-.091	-.168	.002	-.031	.066	.316	-.188	.133	-.036	.233	-.123
Trial 5	-.265	.046	.077	-.047	.010	-.095	-.029	-.029	-.022	.191	.072	.225	-.036	.022	-.050
Elaborative															
Trial 1	.026	-.025	-.266	-.166	-.101	-.107	-.090	.007	.172	-.014	.209	.222	.304	.174	.121
Trial 2	-.303	-.312	-.310	-.242	-.193	-.253	-.350	-.080	.138	-.043	-.163	.025	.256	.333	.034
Trial 3	-.219	-.454	-.494	-.346	-.399	-.405	-.427	-.198	.002	-.306	-.282	-.082	-.091	.270	-.061
Trial 4	-.129	-.247	-.328	-.429	-.344	-.281	-.390	-.449	-.236	-.487	.244	-.011	.011	.045	.006
Trial 5	-.267	-.339	-.323	-.257	-.308	-.315	-.196	-.123	.003	-.313	.115	.100	-.023	-.101	-.090

Table 3.2(c)

	I.1	I.2	I.3	I.4	I.5	E.1	E.2	E.3	E.4	E.5
Inferred										
Trial 1	-									
Trial 2	.450	-								
Trial 3	.257	.447	-							
Trial 4	.083	.278	.630	-						
Trial 5	.342	.435	.584	.600	-					
Elaborative										
Trial 1	.134	-.016	.070	.177	.216	-				
Trial 2	.018	-.187	-.127	.152	.020	.570	-			
Trial 3	-.213	-.298	-.236	.025	-.193	.236	.563	-		
Trial 4	.069	-.062	-.231	-.265	.016	.190	.349	.412	-	
Trial 5	.050	-.107	-.189	.010	-.115	.278	.342	.451	.256	-

Now consider the between response-class correlations. The striking fact here is the extent to which these measures are independent. Multi-occasion intercorrelations of response class frequencies based on inferred, transformed, and elaborative semantic and conditional relations are presented in Table 3.3 to illustrate dependence across elements processed. Correlations involving conditional relations may be somewhat attenuated due to the low frequency of occurrence of these response classes. The simplex structure which appeared for the first four trials in the previous matrix also appears here. Some degree of correlation occurs for particular response-classes across elements processed (semantic or conditional relations), especially for trials occurring in close temporal proximity. There is a relatively strong indication of independence among different response classes as before. If these results are substantiated in future research, the implication would be that multiple processes in comprehension and memory are operating relatively independently, and that measurements of "comprehension" must certainly be multidimensional.

Further analyses of these correlation matrices have recently become possible due to the recent development of numerical estimation procedures which permit the fitting of a wide class of mathematical models to a correlation matrix. For example, it is of theoretical interest to determine whether generation of inferred structural elements is a growth process over trials, implying that processing operations in comprehension involve the gradual construction of a "semantic model" from independently produced elements which are the result of either interpretive or inferential generative operations or, alternatively, inferentially generated elements are built up of semantic elements which are first "built into" the semantic structure by processes of semantic interpretation. If this latter alternative holds, then some argument might be made that inferential processes whould not necessarily be considered a part of comprehension, but rather as representing further processing of the semantic structure built up in comprehending a passage. Suffice it to say that each of these alternatives has associated with it a particular mathematical model generating the simplex property, and that a comparison of fits of the two models may be made. This aspect of the research will be discussed in Chapter 6.

Table 3.3(a)

Multi-Occasion Intercorrelations of Response Class Frequencies Based on Inferred, Transformed and Elaborative Semantic and Conditional Relations ("Implications")

	IR.1	IR.2	IR.3	IR.4	IR.5	II.1	II.2	II.3	II.4	II.5	TR.1	TR.2	TR.3	TR.4	TR.5
Inferred Semantic Relations (TR)															
Trial 1	-														
Trial 2	.450	-													
Trial 3	.257	.447	-												
Trial 4	.083	.278	.630	-											
Trial 5	.342	.435	.584	.600	-										
Inferred Conditional Relations (II)															
Trial 1	.356	.299	.284	.018	.133	-									
Trial 2	.073	.113	.247	.140	.160	.264	-								
Trial 3	.192	.490	.492	.444	.301	.386	.277	-							
Trial 4	.019	-.013	.331	.232	.121	.059	.088	.511	-						
Trial 5	.318	.081	.248	.256	.188	.296	.373	.486	.506	-					
Transformed Semantic Relations (TR)															
Trial 1	-.284	-.019	.164	.107	.156	-.165	.006	-.015	-.036	-.086					
Trial 2	-.153	.245	.157	.150	.194	-.255	-.286	.023	-.150	-.285	.394	-			
Trial 3	-.074	-.012	-.100	-.007	-.126	-.270	-.413	-.250	-.124	-.191	.034	.216	-		
Trial 4	-.139	-.114	-.139	-.197	-.073	-.262	-.167	-.138	-.137	-.122	.126	.351	.150	-	
Trial 5	-.084	-.093	.155	-.012	.106	-.197	-.223	-.138	.027	-.275	.267	.457	.155	.474	-

Table 3.3(b)

	IR.1	IR.2	IR.3	IR.4	IR.5	II.1	II.2	II.3	II.4	II.5	TR.1	TR.2	TR.3	TR.4	TR.5
Transformed Conditional Relations (TR)															
Trial 1	-.284	-.006	.126	.149	.219	-.132	-.139	.261	.282	.016	.405	.346	-.159	-.036	.067
Trial 2	-.251	.034	-.090	.064	-.044	-.115	-.234	-.055	-.080	-.139	.138	.476	.085	-.022	-.071
Trial 3	.295	.269	.039	.026	.134	.075	-.036	.102	-.063	.080	-.053	.355	.145	.283	-.008
Trial 4	.137	.074	-.055	-.081	-.022	.054	.111	.066	-.071	.206	-.060	-.091	-.161	.349	.090
Trial 5	.164	.025	.287	.113	.323	.156	.061	.139	.423	.127	.043	.004	-.151	.049	.374
Elaborative Semantic Relations (ER)															
Trial 1	.134	-.016	.070	.177	.216	-.010	-.059	-.136	-.132	-.131	-.108	.087	-.252	.002	.076
Trial 2	.018	-.187	-.127	.152	.020	-.165	-.253	-.175	-.038	-.114	-.082	.092	.218	-.016	-.020
Trial 3	-.213	-.298	-.236	.025	-.193	-.217	-.284	-.478	-.329	-.382	.069	.195	.270	.059	.078
Trial 4	.069	-.062	-.231	-.265	.016	.027	-.222	-.266	-.293	-.288	-.032	-.045	.278	.182	.021
Trial 5	.050	-.107	-.189	.010	-.115	-.065	-.217	-.277	-.302	-.200	.056	-.025	.122	-.221	-.030
Elaborative Conditional Relations (EI)															
Trial 1	.210	-.101	.035	-.136	.101	.035	.025	-.134	-.070	.023	-.054	-.061	-.075	.020	.135
Trial 2	.028	.040	.293	.241	.275	.352	-.141	.094	.011	.161	-.058	-.105	.202	-.219	-.063
Trial 3	-.032	-.227	.036	.089	-.188	.135	-.151	-.200	.162	.008	-.034	-.058	.223	-.025	.045
Trial 4	.029	.061	.102	.061	.090	.332	.026	.079	-.147	.114	.113	.123	.103	.112	.037
Trial 5	-.010	-.043	.201	.226	.050	-.012	-.170	.024	.092	.062	.459	.205	.066	.159	.196

Table 3.3(c)

	TI.1	TI.2	TI.3	TI.4	TI.5	ER.1	ER.2	ER.3	ER.4	ER.5	EI.1	EI.2	EI.3	EI.4	EI.5
Tr. Imp.															
Trial 1	-														
Trial 2	.283	-													
Trial 3	.204	.273	-												
Trial 4	.129	-.191	.354	-											
Trial 5	.120	-.059	.039	-.015	-										
El. Rel.															
Trial 1	.201	-.072	.182	-.114	.093	-									
Trial 2	.066	-.096	.271	-.272	.073	.570	-								
Trial 3	-.127	.294	.154	-.359	-.105	.236	.563	-							
Trial 4	-.149	-.045	-.007	-.297	.095	.190	.349	.412	-						
Trial 5	.030	-.038	-.076	-.101	-.166	.278	.342	.451	.256	-					
El. Imp.															
Trial 1	.007	-.094	.050	-.018	.127	.158	-.005	-.208	-.013	-.126	-				
Trial 2	-.008	.137	.043	-.226	.126	.050	.189	.195	.177	.191	.214	-			
Trial 3	-.187	.086	.024	-.233	.195	.150	.436	.458	.120	.155	-.072	.305	-		
Trial 4	-.039	.182	.316	-.042	.115	.109	.205	.290	.181	.029	-.099	.458	.285	-	
Trial 5	.318	.131	.116	.046	.045	.147	.140	.162	-.124	.294	-.047	.213	.202	.138	-

CHAPTER 4

A PROCESS MODEL FOR COMPREHENSION AND SEMANTIC MEMORY

4.1 General Considerations

In the previous chapter, a conception of comprehension as an attempt by a listener to "infer" conceptual and relational information which a speaker is attempting to communicate, from a string of linguistic elements which incompletely and imperfectly encode this information, was presented. The question to be explored in this chapter is, "By what sequence of processing operations is this feat accomplished?" A related question emphasizes the limitations on our ability to understand discourse. It asks "What are the limits on the amount of conceptual and relational information which can be acquired from a discourse and retained for subsequent use?" and "What are the sources of such limitations on processing capacity and how does the processing sequence adjust to these limitations?" A third question, which must be asked simultaneously, is that of process invariance (cf. Chapter 2), viz. "To what extent is the sequence of processing operations in discourse comprehension and semantic memory fixed or invariant over a wide range of characteristics of discourses, discourse contexts, temporal conditions, and other variables; and to what extent are these processes invariant developmentally and over individuals?" Given our present state of knowledge about these matters (see Chapters 1 and 2) and since a principal objective in developing a process model is to provide a conceptual framework within which specific questions can be raised, in this chapter we will attempt to develop a model which is both consistent with process models which have proven to be reasonably satisfactory in accounting for other cognitive capabilities (e.g. memory, pattern recognition) and sufficiently general that more specific process models can be considered as special cases of the general model.

In Chapter 1, three main components of a description of the processes which underlie the ability to comprehend a discourse and remember information acquired from a discourse were identified. The first component consists of a structural description of the discourse which is input to a subject. A minimal description of natural-language discourse will have to include a description at several levels: a description of its phonological characteristics; its surface structure, i.e. words plus syntactic markers and order information; its syntactic structure, i.e. grammatical characteristics; and its "literal" semantic structure, i.e. the relational network which is common to and explicitly represented in surface sentences which are identical in their literal meaning. Recent work in linguistic semantics (cf. Lakoff, 1972; Fillmore and Langendon, 1971; Chafe, 1972) has made it increasingly clear that the levels of linguistic description listed above will not suffice as a complete description of a textual input. "Rules of conversation," "presuppositions," and the like all point to the need for some sort of expanded semantic representation which includes semantic information which "must" be presupposed, as well as that which is explicitly encoded in a text. In fact, the problem of semantic representation appears to be open-ended in the sense that it may not be possible to decide how much information to include in an expanded semantic model of a discourse--expanded beyond the literal meaning of a text.

The second main component consists of a structural representation of the semantic information in memory which has been acquired when an input text has been understood. The problem is to describe precisely what has been acquired. Experiments such as that of Sachs (1967) which demonstrate that information concerning the form of surface expression of information is not retained in recognition memory for sentences, suggest that the problem of identifying the form in which information is represented in memory is related to the problem of specifying a semantic description of a discourse. Thus, one might adopt the research strategy of considering a semantic model developed as a description of linguistic inputs as an hypothetical structural model for semantic information in memory. To the extent that the semantic model leads to successful behavioral predictions, then evidence may be accumulated in favor of a representation in memory which is based on the semantic model. To the extent that human cognition is "language dominated," it appears reasonable to entertain such an hypothesis.

The third main component consists of a sequence of processing operations which operate on an input discourse and which result in the semantic structural information which is represented in memory. While a complete description of these processes will have to include a detailed account of precisely what linguistic information is utilized at each descriptive level and how that information is utilized in acquiring semantic information from discourse, quite a bit can be said about the general characteristics of the sequence of processing operations without a detailed account of the processing of specific discourse characteristics. The existence of levels of linguistic information--phonological, syntactic, semantic--imply that the processor must be capable of utilizing information at each level. This chapter will attempt to outline some of these processing capabilities in a general way to provide a more detailed framework for the research questions raised at the end of Chapter 2 and in subsequent chapters.

4.2 Generating Semantic Information from Discourse

Suppose that a spoken discourse is input to a subject and that the structural characteristics of the discourse can be specified, including its phonological, surface, syntactic, and semantic characteristics. Suppose also, that we are able to monitor that information which the subject acquires as the discourse is presented. If, in fact, that information has a linguistically based semantic form of representation, what capabilities must the subject have to generate this information? Consider first the question of what elements of the input are processed. Limits of memory span obviously place some limits on the number of elements which can be processed at any one time, opening the question of just what elements are selected to be processed as units.

Identification of "units" or elements of an input discourse involves three considerations: level, type, and size (see Figure 4.1). At the phonological level, work on speech perception appears to have identified the syllable as the smallest phonological unit and there is substantial evidence that larger elements may be the primary units processed (cf. Neisser, 1967; Bever, 1970). Phonological elements may also be classified with respect to particular phonetic features or linguistic functions. Note that Bever (1970) has pointed out that even at the phonological level, different processing strategies may lead to different phonological units being processed. At the level of surface structure, the informational input consists of an ordered sequence of words and syntactic markers which results from the processing of the phonological information extracted from the acoustic input. The units which are processed can consist of individual words plus syntactic markers, word groups (phrases), clauses, or sentences. The size of the unit processed is undoubtedly affected by syntactic and semantic characteristics of the input discourse and by other conditions which affect the processing strategies of the subject. Types of elements of the surface structure may be identified on the basis of their syntactic and semantic functions. For example, word types such as content words, function words, parts of speech, animate or inanimate nouns, and active or stative verbs may be identified; or, the type of element selected as a unit to-be-processed may be based on further syntactic or semantic analysis of the sentence, e.g., the agent of an action, the result of an action.

At the syntactic level, units processed consist of syntactically interpreted (classified) elements or strings of elements from the surface structure which have been generated by the subject. Thus, if the units in the surface structure consist of words plus syntactic markers, syntactic units may consist of words or word groups together with their identified role in syntax, e.g. in terms of systemic grammar, a noun group may be a subject, object, complement, indicate time, or be the possessor for another noun group (cf. Winograd, 1972). Thus, size of a syntactic element refers to the amount of information in the syntactic unit and type refers to its classification within a grammar. Again, particular elements selected as units for subsequent processing may reflect different processing strategies of the subject.

At the semantic level, the elements which may be the object of processing operations in comprehension and memory are identified in a semantic model such as that presented in Chapter 9. The smallest such element arrived at in the development of the semantic model of Chapter 9 is the single lexical designator denoting a concept or class. Since a concept may be thought of as the intersection of a set of component

ELEMENTS PROCESSED

Level:	phonological structure surface structure syntactic structure semantic structure	
Type:	surface structure:	e.g. content words, function words, syntactic markers
	syntactic structure:	e.g. verb groups, noun groups, preposition groups, adjective groups, subject, object
	semantic structure:	constituent elements of semantic network
Size:	surface structure:	words, syntactic markers, phrases, clauses, sentences, sentence strings
	syntactic structure	e.g. prepositions, preposition group, clause
	semantic structure:	concepts, semantic relations, structures, logical relations, logical structures

PROCESSES

Processing Levels:	phonetic interpreter surface structure generator parser semantic interpreter semantic structure generator	
Constituent Processes:	selection:	e.g. surface, semantic, inferential
	storage, retrieval	
	generative processes:	e.g. encoding, generative reasoning, unconstrained generative processes
	verification:	identity, derivational match
	transfer of control	

Figure 4.1

Classification of possible elements of a description of an input discourse and processes in acquisition of semantic information from a discourse.

semantic features or, alternatively, as a network of semantic relations connected to a node in memory corresponding to a lexical element, there certainly is an issue concerning the size of any particular concept-class for a given discourse. Types of concepts may be based on particular semantic features, e.g. animateness, or on the basis of the semantic function of the concept in the discourse. The next smallest semantic unit is a relational triple consisting of two concepts connected by a single semantic relation. Types of relations may be identified according to the particular semantic relations designated in the semantic model (see Table 9.1). Still larger units are possible: structures consisting of parts of the semantic network consisting of several concepts and the relations connecting them; logical (conditional) relations consisting of two propositions (semantic relations or semantic structures) connected by a conditional relation: and logical structures. Thus semantic elements processed as units may also be classified in terms of both type and size (or complexity). It should be noted that at each level, a structural element is _selected_ by the subject as a unit to be processed,that this selection is probably not independent from level to level, and that this selection may be influenced by a variety of factors. Thus any further specification of precisely _what_ "the" units are that are processed at each level will require that we be able to describe in detail the processing activities of the subject.

Now consider the question of _how_ information is utilized at each descriptive level in acquiring conceptual and relational information from a discourse. The fact that the structural information contained in a discourse can be represented at several levels indicates that there must be corresponding _levels_ of _processing_ through which information at each level is extracted from a discourse and utilized by the subject in developing a semantic model based on the input. The problem, then, is to describe the _constituent_ _processes_ at each level of processing and to allow for transfer of control from one level to another, i.e. for processing operations at one level to be dependent on processing operations at another (usually "higher") level. This latter characteristic is obviously necessary to interpret syntactic and semantic ambiguities, pronominal reference, and the like. Transfer of control may also be involved in, for example, the routine selection of a unit of a surface sequence on the basis of its semantic function. A list of processing levels and constituent processes is found in Figure 4.1 and a flow chart representation of the general organization of the levels of processing in generating semantic information from discourse is given in Figure 4.2. The sequence of processing operations which we suppose occurs in generating semantic information from linguistic inputs consists roughly of the following sequence of operations: (1) generating a surface structure from sensory inputs, (2) syntactic analysis, (3) semantic interpretation (including recognition of lexical elements and semantic interpretation of syntactic relations), and (4) generative operations on retrieved semantic information and on semantic information resulting from the interpretation of the input. Selection and verification (matching) processes are supposed to operate as a part of each of these operations, and information storage can occur at any point in the sequence. Thus, the surface sentence "He moved the new car from the road to the garage" (1) is generated from acoustic inputs; (2) certain syntactic relations are identified (e.g. surface subject, verb, surface object, prepositional phrases) and input to the semantic interpreter together with the surface sentence; (3) lexical labels in long term memory corresponding to lexical elements in the input are retrieved from long term memory, matched to input elements, and used together with the syntactic information to generate a proposition (semantic representation)[1]; (4) additional semantic information structurally related to the proposition may be retrieved as a part of additional processing operations on the semantic information [e.g. as in identifying the pronoun "he" as "John" (say) on the basis of context]. For a discourse (rather than a single isolated sentence), a substantial amount of processing of the sort indicated by stages (4) and (5) would be expected to occur. We would also expect very little information resulting from stages (1) and (2) to be stored in long term memory.

According to this model, at each level of processing, a sequence of processing events occurs which may involve a number of constituent operations: (1) selection: any operations which segment or restrict that information which is to be processed; (2) storage: maintenance of information both in a limited capacity short term memory buffer and on a long term basis; (3) retrieval of information from short or long term memory: (4) operations which generate surface or semantic information from informational inputs and from information retrieved from long term memory; (5) verification (matching) operations which match generated elements against previously generated elements, and (6) control processes which transfer control from one level of processing to another. Thus, the surface sentence "He moved the car from the road to the garage" may be generated by segmenting the phonetic sequence into words (plus syntactic markers), storing the segmented sequence in a rehearsal buffer, retrieving the lexical elements and syntactic markers from memory, matching the retrieved lexical elements and syntactic markers against stored phonetic segments, and then transfering control to the syntactic and semantic components of the system. In Figure 4.2, the solid arrows represent information flow; the dotted arrows indicate that control can be transfered from one component to another. Thus each level of processing can be thought of as a component of the next level in the sequence. Figure 4.3 summarizes the processing events that are supposed to occur at the semantic level as a discourse is presented. (Possible "semantic" control of the parser is ignored in the Figure and in the discussion which follows.) As the phonetic sequence is received, "input" processes result in a syntactically interpreted string of words and syntactic markers which is held in a memory buffer (working memory). A subset of this symbolic string may then be selected for further (semantic) processing. Such selection processes may be under the control of surface and syntactic features of the passage, but cognitive controls of selection (selection strategies) based on semantic features are also possible. For example,

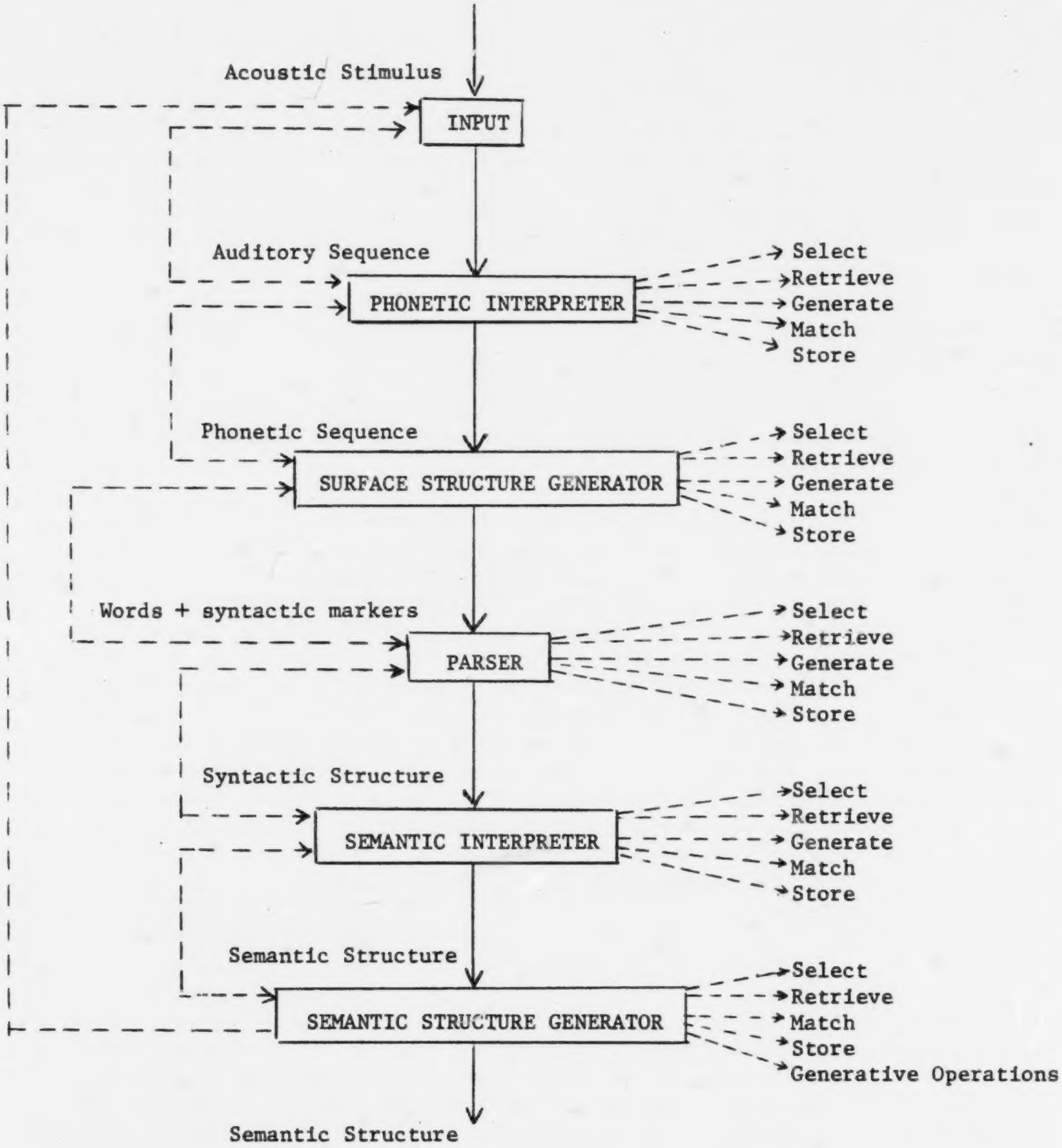

Acoustic Stimulus
INPUT
Auditory Sequence
PHONETIC INTERPRETER
Select
Retrieve
Generate
Match
Store
Phonetic Sequence
SURFACE STRUCTURE GENERATOR
Select
Retrieve
Generate
Match
Store
Words + syntactic markers
PARSER
Select
Retrieve
Generate
Match
Store
Syntactic Structure
SEMANTIC INTERPRETER
Select
Retrieve
Generate
Match
Store
Semantic Structure
SEMANTIC STRUCTURE GENERATOR
Select
Retrieve
Match
Store
Generative Operations
Semantic Structure

Figure 4.2

General organization of the levels of processing in generating semantic information from discourse

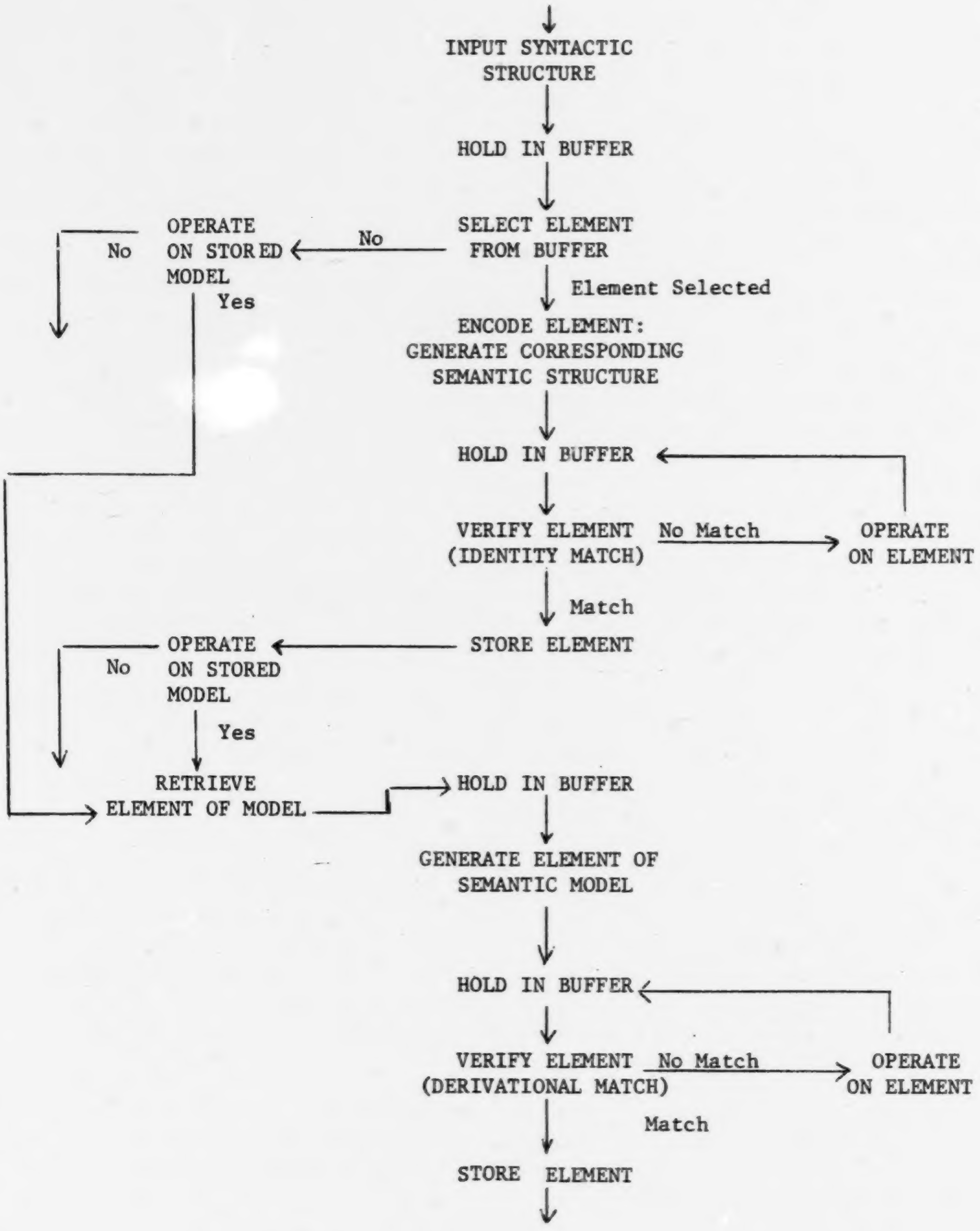

INPUT SYNTACTIC STRUCTURE
HOLD IN BUFFER
SELECT ELEMENT FROM BUFFER
No
OPERATE ON STORED MODEL
No
Yes
Element Selected
ENCODE ELEMENT: GENERATE CORRESPONDING SEMANTIC STRUCTURE
HOLD IN BUFFER
VERIFY ELEMENT (IDENTITY MATCH)
No Match
OPERATE ON ELEMENT
Match
STORE ELEMENT
OPERATE ON STORED MODEL
No
Yes
RETRIEVE ELEMENT OF MODEL
HOLD IN BUFFER
GENERATE ELEMENT OF SEMANTIC MODEL
HOLD IN BUFFER
VERIFY ELEMENT (DERIVATIONAL MATCH)
No Match
OPERATE ON ELEMENT
Match
STORE ELEMENT

Figure 4.3

Some constituent processing operations in discourse comprehension semantic features might be expected to become increasingly important in influencing the selection of information from the input as the subject proceeds through a long passage and builds his own "semantic model" of the passage. In the present model, a distinction is made between three types of selection processes (see Figure 4.1). This distinction is based on whether or not selection is based on surface (incl. syntactic) features of the discourse, semantic features, or is the result of evaluative operations on the semantic content of the essay (as, for example, when an "idea" is selected because of its relations to other "ideas" in the passage). Selection which is based on such evaluative judgment, and which represents a "decision-to-process" resulting from (possibly complex) cognitive operations on the content of the passage, will be referred to as inferential selection; selection which is not based on such inferential evaluation but rather on surface or semantic features of the text will be referred to either as surface selection or semantic selection respectively. Surface selection would result if, for example, a listener selected elements in response to such surface characteristics of a text as inflectional emphasis of a speaker, features of syntax, or sequential or temporal features of the text. In most instances surface, semantic, and inferential selection processes probably operate in complement to one another. For example, a paragraph structure may influence selection of the topic sentence, while at the same time, inferences based on the content of the paragraph may influence selection of the ideas represented in the topic sentence as central to an understanding of the paragraph.

As the processing sequence proceeds, once an element of the input is selected, then the element is encoded (semantically interpreted) through the generation of a semantic element corresponding to the selected element. Such generative operations will be referred to as interpretive processes. The generation of a semantic element necessarily involves retrieval of semantic elements from long term memory. Since some constraints must govern what is generated, it is supposed next that a generated semantic element must be verified in some way against the selected input element. Processes associated with evaluating the correspondence between a generated element of the semantic model and a selected element of the input string will be called verification processes. The simplest sort of verification (which would be expected to occur at the beginning of a passage) is that of an identity match, i.e., verification that the semantic element may be expressed by the corresponding element of the stored surface structure. Following verification (and depending on time constraints), the element of the semantic model may be operated upon and transformed, the result of the transformation verified, et cetera. Resulting semantic elements are stored in long term memory.

As this processing sequence recycles with the input of successive elements of the input string, the nature of selection, generative processes, verification, and operations on semantic elements might be expected to change as semantic elements are generated which were not explicitly present in the input text. The stages of such processing involving operations on the semantic content are outlined in the lower half of Figure 4.3. Thus, in addition to verification based on an identity match, verification based on structural features of the stored "semantic model" becomes theoretically possible as the "model" develops a well formed structure. Thus, operations on the stored semantic model would be expected to occur resulting in the generation of structural elements not corresponding to explicitly presented elements. Verification of these elements, then, must involve criteria other than that of an identity match. Possibilities include verification of class correspondence in which the generated concept includes or is included in the input concept; verification of implication in which the generated concept implies or is implied by previously generated semantic structures (or both); and verification of noncontradiction in which the generated concept does not contradict previously generated structures.[2] As was indicated in Chapter 3, these categories of verification correspond closely to judgments that must be made in scoring subjects' protocols. An identification of categories of generative processes can be made which is based on possible types of verification involving the generated concept. Thus in addition to encoding (generation of identities or imperfectly discriminated elements), one can identify processes of generative inference (generation of inferences or elements which imply and/or are implied by previously generated structures), and of elaboration (generation of elements which, while they are not inferentially derivable from the previously generated structure, do not contradict that structure). Elaboration probably includes the generation of semantic elements which are often categorized as linguistic presuppositions. Finally, contradictory elaborative elements may be generated if no verification takes place or if the verification is faulty. Such elements may also be considered to be transformations of inferentially derivable elements and thus their interpretation may be ambiguous. A great many operations on semantic information may be identified. In fact, these operations represent the entire set of possible cognitive operations on any element of semantic content.

4.3 Generating Discourse from Semantic Information

Having developed the outlines of a model describing the processes involved in acquiring semantic information from natural-language discourse, how might the processes involved in verbally reconstructing this information be described? While such a description is an interesting problem in its own right, it is also necessary to specify the processes involved in verbally reconstructing acquired semantic information in order to identify possible ambiguities in the interpretation of classes of responses obtained from the recall (meaning reconstruction) task as resulting from particular processing operations during acquisition.

Verbal reconstruction of (previously acquired) semantic information involves processing the same elements as those identified in Figure 4.1;

it also involves similar levels of processing and many of the same constituent processes. The processing levels most likely to be involved in speech production involve (1) the generation of semantic structures, (2) the generation of surface expressions by the application of rules of expression to generate surface sentences which express a semantic structure, and (3) articulatory or lexicographic processes which result in either a spoken or written output sequence. The sequence of processing operations which we suppose occurs in verbally reconstructing acquired knowledge is as follows. A directed search of stored semantic information in long term memory (including possible operations on retrieved semantic information, e.g. inferential search) results in the retrieval of a semantic structure consisting of conceptual and relational information, which is held in a short term memory buffer. Then an element is selected from the semantic structure held in the buffer, the selected element is possibly operated on, and rules of expression are applied to generate a grammatical string of words and syntactic markers. The surface expression may be verified and finally output by means of articulatory or lexicographic processes.

The meaning reconstruction task clearly involves both sequences of processing operations--those which occur during input as semantic information is acquired, and those which occur during output when this information is retrieved and expressed linguistically. In Chapter 3, various classes of responses were identified which are obtained from subjects' verbal reconstructions of knowledge acquired from a discourse (Figure 3.13). These response classes were identified with particular processing operations. Since similar processes can occur both during input as a semantic representation of a discourse is built up in memory and during output as semantic information is retrieved or generated from retrieved information and expressed linguistically, a response in a particular class may be indicative of particular processing operations occurring either during input, during output, or both. Thus, for example, if subject-generated inferred semantic relations are observed in a subject's recall protocol, they may have been generated at input as the discourse was presented, or they may be the result of inferential processes which occurred during output as semantic information acquired during input was reconstructed. This ambiguity with regard to whether a given response is the result of a process or processes occurring at input or at output is encountered in any learning task in which the recall method is used to assess learning. In Chapter 6 we will investigate this question with particular reference to the occurrence or nonoccurrence of generative processes (inferential and elaborative) during input. Clearly, if comprehension involves "an attempt by a listener to 'infer' conceptual and relational information which a speaker is attempting to communicate, from a string of linguistic elements which incompletely and imperfectly encode this information," then generative processes must occur at input--as semantic information is being acquired.

CHAPTER 5

EFFECTS OF CONTEXT-INDUCED COGNITIVE OPERATIONS

5.1 Introduction

In the previous chapters a conception of discourse comprehension as involving three main components -- a structural model of a discourse presented to a subject, a structural model of that information which is acquired from an input discourse, and an account of the sequence of processing operations which result in the acquired information -- was developed; one semantic structural model and a procedure for scoring semantic information contained in a subject's verbal reconstruction of knowledge acquired from a discourse which is based on the semantic model were described; and a research strategy involving inferring characteristics of the sequence of processing operations in comprehension and semantic memory from observations of specific sorts of semantic information in subject's recall protocols and observations of the effects of particular contextual conditions on acquired elements of semantic information was presented. Elements of semantic information, it was seen, vary in both type and size (or complexity, cf. Figure 4.1) and semantic elements in a subject's protocol may be either reconstructions of elements which were explicitly coded in a presented discourse or self-generated. Self-generated elements in principle may be classified on the basis of the specific cognitive operations which resulted in those elements. Also, reproduced elements may be represented in subjects' protocols in transformed or altered form. It remains to show precisely how relative frequencies of response classes such as these (cf. Figure 3.13) relate to specific hypotheses about information processing operations in comprehension and semantic memory. The development of such a set of hypotheses also will indicate additional reasons why the processing of discourse should be different from the processing of single sentences.

The present chapter will develop a set of hypotheses which are concerned with those processes which are involved at the semantic level in normal comprehension and with the manner in which those processes change with repeated exposures to a discourse and in different discourse contexts. A principal question underlying many of these hypotheses concerns whether our basic conception of the language comprehender should be that of a primarily interpretive system (which can operate generatively when required to do so by the constraints of a particular discourse or discourse context), or that of a generative system (such as that described in Chapter 4). The chapter will then present the principal experimental results which pertain to these hypotheses: results concerning mean response class frequencies. Two other sources of empirical information concerning normal processes in discourse comprehension and concerning process invariance will be discussed in later chapters: response class intercorrelations computed with different degrees of exposure to the text, and correlations of these response measures with measures of subjects' performance levels on a set of narrowly defined ability tests. Hypotheses concerning the dependence structures of response measures which involve questions of process independence and alternative sources of observed stochastic growth, and hypotheses concerning sources of individual differences in semantic information acquired will be offered after the principal experimental results have been examined.

5.2 Method

Subjects. One hundred forty-one undergraduates from California State College at Hayward, who were paid for their services, served as subjects. Most of the students were enrolled in introductory psychology courses. Sixty-six subjects were male; seventy-five were female.

Material. A 503 word essay was constructed from that used by Dawes (1966) consisting of 30 independent clauses and 25 dependent clauses. The passage consisted entirely of declarative sentences; there were five passive transformations and two negatives. No sentences were ambiguous. The complete text of the passage may be found in Appendix A. The passage was analysed according to the procedures for semantic analysis presented in Chapter 3 into the relational structure presented in Figures 3.1 to 3.8. This structural representation was taken as the base semantic (propositional) structure for the essay.

A number of problems with this and other methods of semantic analysis have already been identified; an additional major problem with any method is that no explicit set of rules exists for converting a text into its semantic structure. Even given a detailed linguistically-based semantic structural model (such as that of Chapter 9), this problem still seems very far from solution. A solution to the problem would require not only a semantic model, but also a surface grammar and a set of rules of expression mapping from a semantic structure to its surface expressions. The present procedures for generating a semantic representation appeal to linguistic intuitions concerning the set of surface expressions which are considered to be paraphrases. Nevertheless, a semantic model of any text can be defined to represent the text and used as a template against which subject's protocols are scored even though there may be an element of arbitrariness in the representation.

A high quality tape recording of the passage was made using an Ampex 861 tape recorder and a Schure Model 545 microphone (7 1/2 i.p.s.). The passage was read at a moderate rate by an experienced male reader; reading time averaged about 3 minutes.

Design. Subjects were randomly assigned to three experimental groups consisting of 47, 49, and 45 subjects. The first group (A) consisted of 18 males and 29 females; group B had 26 males and 23 females, and group C had 22 males and 23 females. The three experimental groups correspond to the three experimental conditions described in Chapter 2. In each condition, subjects were repeatedly presented the five hundred word essay entitled Circle Island.

In the first experimental condition (A), subjects were told that the material which they would hear would consist of a passage which describes a socio-political problem on an hypothetical island, involving a canal, a threatened civil war, and the probable collapse of the island's economy, and were instructed only that they were to recount in writing what they had heard. They were also told that they were not expected to reproduce the passage verbatim. In the second condition (B), subjects were told that they were participating in an experiment concerned both with investigating the ability of individuals to remember spoken material and to use this information to solve problems, presented with a problem involving the content of the essay (but giving no additional information), and presented with instructions designed to direct them to think about how to solve the problem while they try to remember information from the essay. The problem involved having the subject generate as many alternate solutions as he could for the island's problems, using the information given in the essay concerning the island's social, economic, and political situation. The problem was designed to cause the subject to operate inferentially on a large number of the semantic relations conveyed in the structure of the passage. Since the "level of difficulty" of the passage was about that of a somewhat involved newspaper story, it was felt that if this context produced predictable effects on processes in comprehension and memory, the result would be likely to be generalizable to typical situations involving verbal communication and would certainly generalize to intellectually demanding comprehension tasks.

In the third condition, condition (C), subjects worked only on developing solutions to the problem involving the island. However, after three trials of exposure to the text and work on solutions, on the fourth trial these subjects were asked to recount the essay in writing. Subjects in conditions A and B recounted the story four times, once after each exposure to the text. After the fourth trial, all subjects were presented with the problem solving task. Thus condition A involved "incidental problem solving" and condition C involved "incidental memory". The temporal course of events over the four trials and subsequent problem solving were kept precisely equivalent for the three conditions. In all three conditions, exactly the same prior information about the content of the passage was contained in the instructions.

All subjects returned one week after the first session to take a battery of ability tests, and were asked at that time (before administration of the tests) to recount in writing their best recollection of the passage. Subjects were tested in groups varying between ten and fifteen persons in two three-hour sessions held one week apart. Two experimenters were used; approximately half of the subjects in each group were tested by each experimenter. Subjects were instructed not to talk about the experiment. The first session consisted of the learning and problem solving tasks, a test of set relations, and the administration of a strategy assessment questionnaire; the second session consisted of one (unexpected) written recall followed by the administration of a battery of ability tests.

Procedure. Subjects in groups A and B were read the following instructions:

In this session we are in effect trying to simulate part of a classroom situation. The material on the tape which you will hear is artificial since we had to make sure that it was equally unfamiliar to everyone. It is also much shorter than a typical lecture, but listen to it as if it were being given by a lecturer. However, do not take notes.

(Demonstrate) Begin by removing the first booklet from the envelope. Read the instructions along with me as I read them out loud. (Read instructions and answer any questions).

Instructions, Group A:

1. You are participating in an experiment which is concerned with investigating the ability of individuals to remember spoken material. The material will consist of a passage which describes a socio-political problem on a hypothetical island, involving a canal, a threatened civil war, and the probable collapse of the island's economy.

2. When the experimenter starts the tape recorder, you will hear the first presentation of the passage. Your task is going to be to recount in writing what you have heard. In accomplishing this, you must not take notes but rely only on your memory. After the passage has been played, you will be given time to write your best recollection. You are not expected to reproduce the passage word-for-word. Please use a prose style (complete sentences) as often as you can.

3. You will be given 15 minutes for writing. The experimenter will tell you when to begin and when to stop. The amount of time allotted for writing will be more than sufficient for some of you. Should you finish before the experimenter gives the signal to stop, remain in your seat and wait for the next presentation.

   Since we are interested in how your memory changes with additional opportunities to hear the material, we will repeat this procedure 4 times. Before each new presentation of the passage and while you are writing, you should not look back at what you have written for previous presentations. Nor should you turn the pages and read ahead in your instructions booklet until told to do so by the experimenter.

Instructions, Group B:

1. You are participating in an experiment concerned with investigating the ability of individuals to remember spoken material and use this information to solve problems. You may think of this experiment as a study of how you are able to remember and use information which you hear in a class lecture, when the lecturer states a problem in advance and then asks you to think about this problem as he presents the facts and ideas pertaining to it. In the experiment which follows, you will hear a short "lecture" which describes a socio-political problem on a hypothetical island, involving a canal, a threatened civil war, and the probable collapse of the island's economy. Some of you may typically think a lot about problem solutions as you hear such a lecture, while others may only concentrate on taking in the facts. We would like all of you to think about problem solutions as you try to "take in" the facts. Thus, we would like you to both remember the facts and ideas presented, as well as use them in understanding and trying to resolve the problem.

2. Although our experiment is designed to "simulate" a class-room situation, we want to avoid stating the problem in a formal way -- we don't want it to resemble an exam question. Therefore, to make your task more interesting, and to involve you in a meaningful and imaginative approach to problem solving, we would like for you to take the role of a person directly affected by the facts and events on the island. Imagine that you live in a country that is dependent on this island for certain exports. The imminent collapse of the island's economy poses a grave threat to your country. Further, imagine that you are an intelligence agent for your government and you have been given the following assignment:

   Familiarize yourself with the situation on the island, then come up with as many alternative plans as you can which will:

   1. Prevent a civil war.
   2. Get a canal built without penalizing any particular group.

   (Note: You may use any and all methods to achieve these goals except those which necessitate military intervention or which change the island's present form of government.)

3. Your problem is thus twofold. It is first to remember as much as possible about the situation on the island, while at the same time develop a set of alternative solutions to the problem. The experiment will be divided into two parts. In the first part, the passage containing information about the island will be presented. While you should be thinking about how to accomplish your assignment as an intelligence agent, your primary task during this part will be to remember as much information about the island as you can. After the passage is read, you will be asked to recount in writing what you have heard. In accomplishing this, you must not take notes but rely only on your memory. After the passage has been played, you will be given time to write your best recollection. You are not expected to reproduce the passage word-for-word. Please use a prose style (complete sentences) as often as you can. [Paragraph 3 of the instructions given group A follows.]

4. The second part of the experiment will involve your describing and working out in writing your solutions to the island's problems. The experimenter will tell you when to begin the second part of the experiment.

5. (Demonstrate) Now turn to the next page. It should be a clean sheet of lined paper. Write the number 1 in the top margin (demonstrate). I will now start the tape recorder and play the first presentation. (Play trial 1)

6. I would now like you to write down as much as you can remember of what you've just heard. You are not expected to do this word-for-word. You may use your own words but please use complete sentences and write legibly. You will have a maximum of 15 minutes to

accomplish this. Ready --- GO! (start watch) (Repeat instructions 5 and 6 for trials 2 and 3)

7. STOP! (stop watch) Please turn to the next clean sheet of paper and write a 4 in the top margin. I will now replay the passage for the final time. (Play tape)

8. Since this is your final trial, I would like to review the instructions again briefly to be sure that you understand your task. For trial 4, we would again like you to recount in writing, as accurately as possible, the passage which you have heard. You are not expected to reproduce the passage word-for-word. Use a prose style (complete sentences) as often as you can.

   You will be given 15 minutes for writing your best recollection of the passage. The amount of time allotted for writing will be more than sufficient for some of you. Should you finish before the experimenter gives the signal to stop, remain in your seat and wait for the experimenter's instructions. Do not look back at what you have written for previous presentations. Do not turn pages in the booklet until told to do so by the experimenter. Ready -- GO!

9. STOP! (stop watch) (Demonstrate) Now turn the pages in the booklet until you arrive at the next dittoed page of instructions. Read the instructions as I read them outloud. (Read instructions and answer questions)

Instructions, Group A:

10. Now that you are thoroughly familiar with the situation on the island, we want to see how you can put this information to use. Your next task will be to work out solutions to the island's problems. We would like you to approach this task as follows:

11. Imagine that you live in a country that is dependent on this island for certain exports. The imminent collapse of the island's economy poses a grave threat to your country. Your role is that of an intelligence agent for your government who has been given the following assignment:

    Come up with as many alternative plans as you can which will:

    1. Prevent a civil war.
    2. Get the canal built without penalizing any particular group.

    (Note: You may use any and all methods to achieve these goals except those which necessitate military intervention or which change the island's present form of government.)

    In doing this you must not look back at what you have written, but rely only on your memory.

12. Assume that these plans will be presented to your country's Committee on Foreign Policy, and that some members of this

> committee are not familiar with the island or what has transpired there. Therefore, write your plans on the following pages in a clear, concise manner so that the committee members can easily understand what you have in mind. Do this by using the facts you remember about the island and the situation there to specify how and why each plan will change this situation so as to fulfill the assignment.
>
> Here is an example of a very poor plan:
>
> 1. Have our airforce bomb them back into the stone age.
>
> Although this plan might prevent a civil war, it obviously does not fulfill the assignment. It does not take the reality of the situation into account, nor does it give the facts explaining how and why this plan would fulfill the assignment. It also violates the restriction from military intervention. Avoid plans of such an unrealistic and incomplete nature.
>
> Number your plans, and separate them so that it will be clear from your writing where one plan ends and the next one begins.
>
> Remember that this problem is open-ended, i.e., it has no single correct solution. We are interested in your ability to come up with many well-formulated and documented plans.

Instructions, Group B:

> Now that you have completed part one of the experiment and are thoroughly familiar with the situation on the island, we want to see how you have put this information to use. Therefore, your next task is going to be to write out your solutions to the island's problems. Remember, we asked you to imagine that you live in a country that is dependent on this island for certain exports. [The remainder of the instructions were identical to those read to group A.]

The subjects then worked for thirty minutes writing down their solutions to the problem.

Subjects in group C read the following instructions. [The preceding instructions read to the subjects were identical to those read to the subjects in groups A and B.]

> You are participating in an experiment concerning the ability of individuals to solve problems based on extensive factual material, aurally presented. In the experiment which follows, you will hear a short "lecture" which describes a socio-political problem on a hypothetical island, involving a canal, a threatened civil war, and the probable collapse of the island's economy. You may think of this experiment as a study of how you are able to use information which you hear in a class lecture, when the lecturer states a problem in advance and then asks you to think about this problem as he presents the facts

> and ideas pertaining to it. [Paragraph 2 given in the instructions to group B then followed, and that was followed by paragraph 12 in the instructions to group A.]
>
> When the experimenter starts the tape recorder, listen carefully to the passage. Do not take notes during the presentation. When the presentation is over, you will be given 15 minutes to work on developing alternative plans of action. Since we are interested in how problem solutions change with additional opportunities to hear the material, we will repeat this procedure 4 times. Before each new presentation of the passage and while you are writing your plans, you should not look back at what you have written for previous presentations. Nor should you turn the pages and read ahead in your instructions booklet until told to do so by the experimenter.

Now turn to the next page. It should be a clean sheet of lined paper. Write the number 1 in the top margin (demonstrate). I will now start the tape and play the first presentation. (Play trial 1.)

I would now like you to write down as many alternative plans as you can. You may tear out the instructions sheet along the dotted line so that you may refer to them as you write. Be sure to describe each solution plan completely. You will have a total of 15 minutes in which to do this. Continue trying to construct alternative plans until time is called. Ready ---- GO'. (start watch)

STOP! (stop watch) Now turn to the next blank sheet of paper and write the number 2 in the top margin. I will now replay the passage. (Play trial 2).

Again, write down as many alternative plans as you can. You should enlarge upon the plans you wrote on the previous trial, and think of as many new plans as you can. Do not look back at what you wrote for the previous trial. You will have a maximum of 15 minutes. Ready --- GO! (start watch) (Repeat last two instructions for trial 3.)

STOP! (Stop watch) Please turn to the next clean sheet of paper and write a 4 in the top margin. I will now replay the passage for the final time (Play trial 4)

Before writing your plans for the final time, please turn the pages in the booklet until you arrive at the next dittoed page of instructions (demonstrate) Read the instructions as I read them aloud. (Read memory instructions and answer any questions)

Memory Instructions, Group C:

> Now, before you write out your final plans, we would like you to recount in writing, as accurately as possible, the passage which you have heard. You are not expected to reproduce the passage word-for-word. Use a prose style (complete sentences) as often as you can.

> You will be given 15 minutes for writing your best recollection of the passage. The experimenter will tell you when to begin and when to stop. The amount of time allotted for writing will be more than sufficient for some of you. Should you finish before the experimenter gives the signal to stop, remain in your seat and wait for the experimenter's instructions to go on with your final solution plans.
>
> Do not look back at what you have written for previous presentations. Do not turn pages in the booklet until told to do so by the experimenter.

In this final trial, you will be given a longer time to enlarge upon previously developed plans and to construct new plans. To be sure that the problem and its constraints are fresh in your mind, we will quickly review the instructions. [The remainder of the instructions were identical to those read to groups A and B.]

Ability measures. All subjects took the following ability texts selected from the Kit of Reference Tests for Cognitive Abilities of French, Ekstrom, and Price (1963): (1) Hidden Patterns (CF-2), (2) Word Arrangement (Fe-3), (3) Inference (Rs-3), (4) Auditory Letter Span (Ms-3), (5) First and Last Names (Ma-3), (6) Theme (Fi-2), (7) Object Naming (Xs-3), (8) Gestault Completion (Cs-1), (9) Controlled Associations (Fa-1), (10) Letter Sets (I-1), (11) Topics (Fi-1), (12) Advanced Vocabulary (V-4), (13) Simile Interpretations (Fe-2), (14) Associations IV (Fa-3), and (15) Four-letter Words (Cs-3). Abilities data will be considered in Chapter 7.

Strategy measures. In an attempt to reliably assess the extent to which subjects adopted specific strategies in acquiring semantic information from a discourse, judgments were obtained concerning strategies employed in remembering the content of the essay. The judgements were obtained after subjects had written their solutions to the problem and using a method of assessment developed for use in list learning tasks (Frederiksen, 1969), by asking the subjects first to study a list of statements of methods or strategies which they may have employed in remembering the content of the essay, presenting them with a series of pages containing the list of statements with randomly selected propositions appearing at the top of each page, and requiring them to check any methods which described how they remembered the idea at the top of the page. A score for each strategy was obtained by summing the number of propositions for which the strategy was checked. A sample proposition and the list of strategy statements follows:

IDEA: The actual governing body is a ten man senate, called the Federal Assembly.

______ 1. No particular strategy. I did not use any particular strategy in trying to remember this idea.

______ 2. Key words by rote. I tried to learn key words, related to this idea, by rote, using these key words in reconstructing the idea.

______ 3. Particular ideas. I tried to concentrate on remembering particular ideas and events and for this reason concentrated on this idea.

______ 4. Central ideas. In remembering this idea, I focused on trying to discover and remember the central ideas of the passage, then related this idea to these central ideas.

______ 5. Details. I tried to remember descriptive details from the expression of this idea in the passage.

______ 6. Ideas in sequence. In remembering this idea, I concentrated on recounting the idea in the sequence in which it occurred in the passage.

______ 7. Ordered in my own way. In remembering this idea, I did not pay particular attention to its position in the sequence of ideas but rather ordered it in my own way.

______ 8. Most important ideas first. I considered some ideas to be more important than others, and in remembering this idea I considered its importance within the passage.

______ 9. Unstated relationships. In remembering this idea, I tried to think of new connections or relationships between this idea and others in the passage -- relationships which were not explicitly stated in the passage.

______ 10. Unusual ideas. I found this idea to be somewhat unusual and took particular note of it since it was an idea which was strange, peculiar, or unexpected.

______ 11. Shifted attention. I frequently shifted my attention from this idea to other ideas in the passage.

______ 12. Visual images. I tried to form visual images suggested by this idea, using these images to help remember the idea.

______ 13. Shifted strategies. I frequently shifted my strategies or approaches to the problem of remembering this idea.

______ 14. Attention to parts. I did not pay attention to the part of the passage expressing this idea every time it was presented, ignoring it in order to concentrate on other parts of the passage.

______ 15. Formed associations. I tried to form associations to the part of the passage expressing this idea and later used these associations in remembering the idea.

______ 16. Classification. I tried to organize or classify ideas within the passage, using this classification in remembering this idea.

_____ 17. Previous knowledge. I tried to relate this idea to my previous knowledge or conceptions related to the subject under discussion.

_____ 18. Illustrations. I tried to think of illustrations or metaphors for this idea.

_____ 19. Systematic method. I tried to utilize a systematic, rational procedure, *i.e.*, I had a "plan" that I followed in remembering this idea.

_____ 20. Noticed effectiveness. If my initial strategy did not seem effective for remembering this idea, I tried a new strategy.

_____ 21. Rote memory. I remembered this idea by learning by rote the phrase that I heard expressing the idea.

_____ 22. Elaboration. I found that this idea suggested additional ideas to me which helped me remember the original idea.

_____ 23. Expository ordering of ideas. In remembering this idea, I ordered it in the sequence of ideas in such a way to facilitate writing an essay which someone could easily understand.

_____ 24. ANY OTHER METHOD USED:

The sentences used were: (1) "A large canal would upset the island's ecological balance", (2) "Circle Island has few rivers and hence a shortage of water", (3) "Beef is the only export of the island", (4) "The island is run democratically", (5) "The senate's job is to carry out the will of the majority", (6) "The main opposition to the canal idea came from the ranchers", (7) "The senate decided that it would be too ecologically dangerous to have a canal that was more than two feet wide and one foot deep", (8) "The farms of the island are small", (9) "The ranchers are much more prosperous than the farmers", (10) "An island scientist, Dr. Carl Oliver, discovered a cheap method of converting salt water into fresh water." Strategies data will be considered in Chapter 7.

Response measures. Semantic response measures were obtained by applying the scoring procedures described in Chapter 3 and consist of the relative frequencies of responses in each subject's protocol in each of the classes listed in Figure 3.13. Each semantic measure was obtained for each trial. A number of surface linguistic counts were also obtained by means of a computer program written for the purpose including certain simple linguistic counts: number of letters, words, independent clauses, dependent clauses, counts of parts of speech, articles, adjectives, pronouns, nouns, adverbs, verbs, prepositions, conjunctions, causal conjunctions; and counts of number of passive, negative, and passive + negative transformations.

5.3 Hypotheses

The basic measures resulting from this experiment consist of the set of scores obtained from matching a subject's recall protocol to the semantic model of the passage Circle Island (using the scoring procedures described in Chapter 3); a response pattern consisting of a set of counts of the number of semantic elements present in a subject's protocol in each of thirteen response classes (Figure 3.13). Two types of semantic elements will be considered: concepts and relations. While more response categories are possible and counts could be obtained separately for different types of relations, parts of a passage, etc., if too many response classes are used, the resulting frequencies of responses in each class become too small to be useful. For groups A and B, these response measures are obtained on each of four trials and on a fifth reminiscence trial; for group C, the measures are obtained on trial 4 and on the reminiscence trial. Since all measures are frequency counts, the data are appropriate for statistical analyses based on the multivariate normal sampling distribution. Hypotheses involving ability and strategy measures will be considered separately in Chapter 7.

The problem in analyzing these data is to extract information relevant to hypotheses concerning first, the nature of the processes which generated the semantic information which subjects acquired from the experimental text, and second, the effects of the contextual conditions and repeated exposures to the text, on these processes. We will begin by considering hypotheses concerning normal processing activities in a "natural" (arbitrary) discourse context, hypotheses which involve only the data obtained under condition A. Considered will be hypotheses concerning (1) limits on processing capacity (given a single exposure to a textual input); (2) extent of adjustment to such limitations through imperfect discrimination or simplification of conceptual information and use of generative processing operations (with a single exposure to a text); (3) effects of repeated exposures on processing limits, simplification, and extent of generative processing; and (4) possible changes occurring in reminescence. These hypotheses will be considered for both conceptual and relational elements. Hypotheses concerning effects of the experimental conditions, which were designed to induce "superordinate" processing operations on semantic information acquired from a passage, will then be considered. Hypotheses will be considered concerning (5) effects of the experimental conditions on generative processing operations and (6) changes in these effects with repeated exposures to the text and (7) in reminiscence. Finally, similar effects will be considered involving comparison of the incidental memory condition with the other two conditions. These latter hypotheses concerning process invariance will involve comparison of experimental groups A and B on five trials, and comparisons among all three groups on trials four and five. Hypotheses concerning the stochastic growth properties of response class measures (over trials), process independence, and the role of generative processes (at input or at output) will be considered in the next chapter. The primary issue which underlies many of the hypotheses to be considered is: should the sequence of processing operations which is involved in normal comprehension be regarded as primarily an interpretive system in which surface and syntactic information present in a text are analysed and interpreted semantically resulting in a representation in memory of the semantic information which was explicitly coded in a text; or should it be regarded as primarily a generative system in which semantic information is generated (in the manner described in the previous chapter) in an attempt to synthesize that conceptual and relational information which a speaker is attempting to express? A classification and statements of specific hypotheses concerning the above issues follows.

I. Hypotheses involving Group A alone [concerning characteristics of processing activities in "normal" comprehension]

A. Limits on processing capacity, trial 1 recall (single presentation)

The processing operations which we suppose are necessary to semantically interpret an input discourse consists of the following sequence. A semantic interpreter must: (1) generate a string of words and syntactic markers from acoustic inputs, (2) identify each concept by retrieving appropriate semantic information, (3) use surface and syntactic information to generate a relational structure linking these conceptual categories, and (4) store the resulting structure. For a single sentence, a certain amount of time would be required for each of these processing operations. Thus, it is reasonable to suppose that elements of surface structure are generated at a time approximately contiguous with the input of the relevant acoustic information (with a lag corresponding to the processing time), that semantic interpretation (concept identification and generation of semantic relations) requires additional processing time and hence occurs with a greater lag after each word phrase or clause and that storage of generated semantic information in long term memory requires still more processing time and occurs largely after a clause or sentence has been presented. These considerations lead to the following expectations when a discourse consisting of multiple sentences is presented:

1. A discourse will normally exceed the capacity of the system to completely process and store all of the semantic information contained in the discourse, since the succession of sentences (clauses) will normally prevent the semantic interpretation and storage of the resulting semantic information from being completed. Thus, the amount of reproduced semantic information (veridical concepts and relations) present in subjects' recall protocols should represent only a fraction of that actually contained (explicitly coded) in the presented discourse.[1]

2. The proportion of relations reproduced should be less than the proportion of concepts reproduced, since the generation of relations connecting concepts

requires more extensive processing than the generation of concepts.

B. Adjustments to limits on processing capacity, trial 1 recall:

Given that these limitations on processing capacity exist for every discourse, it is likely that a semantic information processing system would adjust to these limitations by systemmatically selecting that semantic information which is to be acquired on the basis of either surface or semantic characteristics of the input discourse (or both). Semantic information explicitly represented in a discourse could be systemmatically reduced in the following two ways:

1. Conceptual classes may be simplified or imperfectly discriminated, resulting in incompletely specified conceptual categories (overgeneralized concepts) and relations connecting incompletely specified concepts in subjects' recall protocols.

2. An efficient way to reduce the "informational load" presented by a discourse would be to acquire information generatively. Thus, semantic information may be generated from previously acquired semantic information and from elements selected from the current linguistic input in an attempt to "infer" conceptual and relational information without completely analysing the input discourse (i.e., in the manner described in the previous chapter). Such a method of adjusting to limitations on processing capacity ought to result in the presence of large numbers of inferred concepts and relations in subjects' recalls. One would also expect to find relatively more inferred relations than concepts.

C. Effects of repeated exposures:

Repeated exposures to a text should result in the acquisition of new explicitly coded semantic information on each exposure to the text. As the amount of new information remaining to be acquired decreases, the "informational load" on the comprehension-memory system would be consequently reduced. Thus, repeated trials should result in:

1. Increased frequencies of reproduced (veridical) conceptual and relational elements in subjects' recall protocols;

2. Negatively accelerated increases in frequencies of incompletely specified concepts and relations involving incompletely specified concepts (since progressively less adjustment to limitations on processing capacity would be necessary with successive exposures to a discourse);

3. Negatively accelerated increases in inferred concepts and relations since achieving a reduction of the "informational load" induced by a discourse by generative processing would become less important as the amount of "new information" remaining to be acquired, decreased.

D. Changes in reminiscence:

Changes in frequencies of reproduced, overgeneralized, and inferred concepts and relations in reminiscence reflect the sort of changes described by Bartlett (1932), viz. reductions in the amount of reproduced semantic information and simplification of that information as it is reconstructed. In addition, as previously stored semantic information becomes more difficult to retrieve, one might also expect that more semantic information would be generated inferentially from that conceptual and relational information which is retrieved. These considerations lead to the following expectations.

1. Frequencies of reproduced (veridical) concepts and relations should decrease in reminiscence.

2. Frequencies of overgeneralized concepts and relations involving overgeneralized concepts should increase (simplification).

3. Frequencies of subject-generated inferred concepts and relations should increase.

II. Hypotheses involving Groups A and B [concerning process invariance and effects of the contextual conditions][2]

A. Context invariance of all results hypothesized under I. above:

Insofar as the experimental discourse presents a degree of information load under contextual condition B which is similar to that under condition A, the predictions involving limits in processing capacity and adjustments to limits in processing capacity which were made for contextual condition A should replicate for condition B.

B. Effects of contextual conditions on discrimination of conceptual categories:

While the problem solving context was designed to induce inferential operations on semantic information contained in the presented discourse, it may also increase the "informational load" on a subject. Thus, the extent of simplification of conceptual categories (overgeneralization) may be greater under condition B than under condition A.

C. Effects of contextual conditions on extent of generative processing (single presentation):

If the problem solving context (B) described previously successfully induces "superordinate" processing operations on the conceptual and relational information which is acquired from a discourse, these operations ought to have predictable effects on the specific classes of responses obtained from the semantic analysis of subjects' recall protocols which reflect the affected processing operations. The problem solving task involves, first, considering the present state of Circle Island and the changes of state which are expressed in the passage, and, second, inferring the effects which specific introduced changes would have on the island's state. Thus, the task involves both (1) generating hypothetical events and (2) inferring the effects those hypothetical events would have on the island's state.

1. The operations required by the problem solving task, then, should result in increased generation of inferred relations and (to a lesser degree) concepts -- increased relative to the frequency of these elements in the "natural" discourse context (A).

2. To the extent that the hypothetical information generated in problem solving is incorporated in the semantic structure representing the text, frequencies of elaborative concepts and relations would also be expected to increase in comparison to their frequencies in condition A.

D. Effects of repeated exposure on contextual differences in extent of generative processing:

1. The effects of the contextual conditions on frequencies of inferred concepts and relations predicted above should increase with repeated exposures to the text as a negatively accelerated function. The increased effect is expected since the exploration of consequences of hypothetical actions should increase as more semantic information is acquired from the passage.

2. Since the set of hypothetical actions which may be considered in problem solving is limited and since many of these solutions are likely to be generated after the first exposure to the text, effects of the experimental contexts of frequencies of elaborative concepts and relations ought to be less apparent on trials subsequent to the first.

III. Hypotheses involving Groups A, B, and C [concerning process invariance and effects of the contextual conditions][3]

Under the incidental memory condition, conceptual and relational information explicitly coded in the presented discourse would be expected to be retained only if it were related to problem solution.

Thus, it is reasonable to expect that under the incidental memory condition (C) the hypothesized effects of the contextual conditions on simplification and extent of generative processing (hypotheses IIB and IID) will occur to a greater extent than under condition B. This result should be particularly apparent if the data were expressed as relative frequencies and thus equating the groups in terms of total semantic information acquired from the discourse. It is also reasonable to expect that frequencies of reproduced (veridical) concepts and relations will be less than those obtained under conditions A and B given an equivalent number of exposures to the passage.

A. Inferred concepts and relations:

The experimental groups should be ordered A<B<C in terms of frequencies of inferred concepts and relations. The separation should be greater for relations than for concepts.

B. Elaborative concepts and relations:

The same ordering is expected but with less separation of the groups.

C. Simplification of conceptual categories:

The same ordering is expected with respect to frequencies of overgeneralized concepts.

The import of these predictions should be clear: that even under "normal" (arbitrary) conditions in which a discourse is understood, comprehension involves a process of inferring a speaker's semantic knowledge from fallible and incomplete linguistic inputs; and that the manner in which an individual uses knowledge transmitted in a text will affect the nature of the semantic information he acquires from the text, the means by which he acquires that information, and hence his "comprehension" of the text.

5.4 Results

Results obtained from analyses of mean frequencies of various classes of responses in different contexts are presented in the Tables and Figures which follow. The results will be presented in an order corresponding to that in which the relevant hypotheses were presented. Consider first hypotheses (involving Condition A alone) concerning characteristics of "normal" processing activities, in particular hypotheses involving: (IA) limits on processing capacity, (IB) adjustments to limits on processing capacity, (IC) effects of repeated exposures, and (ID) changes in reminiscence. The results relevant to Hypothesis IA are presented in Table 5.1 and are included in the graph in Figure 5.1. The amount of reproduced conceptual information acquired after a single exposure to a text is about 20 per cent (for condition A). Furthermore, the figure obtained for semantic relations is 8.6 per cent, and for conditional relations the figure is 3.3 per cent. The frequencies of explicit concepts, semantic relations, and conditional relations contained in Circle Island were 92, 68, and 12 respectively. Frequencies of conditional relations were probably much too small to permit reliable estimation of what these proportions would be for a text containing a more extensive logical structure. Hypotheses IBI and IB2 involve the expectation that significant frequencies of overgeneralized and inferred concepts and semantic relations will occur. The relevant data are included in Tables 5.2 and 5.3. Pooled within-group standard deviations may be used to place confidence limits on their corresponding mean frequencies of overgeneralized concepts and relations indicating that the observed frequencies of overgeneralized concepts and relations are statistically significant. Concepts may also be transformed by including too much differentiating information in the concept. Frequencies of such pseudodiscriminated concepts (and semantic relations involving pseudodiscriminated concepts) indicate that this latter process also occurred.

Frequencies of inferred concepts and relations are found in Table 5.3 and plotted in Figure 5.1 (see condition A, trial 1). The results indicate that significant numbers of inferred concepts and semantic relations were generated by the subjects. Especially interesting is the result that with a single exposure to the text, more inferred relations actually were generated than veridical relations were reproduced. The prediction concerning the relative extents of inferential concepts and semantic relations, viz. that relatively more inferred semantic relations than concepts would occur, is confirmed by these data, where frequencies of inferred concepts or semantic relations are taken relative to frequencies of veridical concepts or semantic relations respectively (cf. Figure 5.1). Relative frequencies of conditional relations continue this trend, although the absolute frequencies may be too low to permit generalization to textual materials containing more extensive logical structures (of conditional relations linking propositions, cf. Chapter 9). Significant frequencies of elaborative concepts and semantic relations were also obtained and are reported in Table 5.4.

Results concerning the effects of repeated exposures to a discourse on the acquisition of explicitly coded conceptual and relational information

Table 5.1

Means and Pooled Within-Group Standard Deviations of Frequencies of Veridical Concepts, Semantic Relations, and Conditional Relations Obtained on Trials 1 to 4 and Reminiscence; and Means Expressed as Proportions of Concepts, Semantic Relations, and Conditional Relations in Input Discourse; Conditions A and B

		Mean Absolute Frequencies									
		Condition A			Condition B				Mean Proportions		
Response Class	Trial	male	female	pooled	male	female	pooled	Grand Mean	Condition A	Condition B	Pooled Within-Group Standard Deviations
Veridical Concepts	1	19.33	17.86	18.43	16.96	19.83	18.31	18.50	.200	.199	6.26
	2	30.00	29.83	29.89	25.34	31.57	28.27	29.18	.325	.307	7.94
	3	33.06	36.38	35.11	31.85	38.91	35.16	35.05	.382	.382	9.63
	4	36.72	40.00	38.74	35.73	42.61	38.96	38.77	.421	.423	10.51
	R	32.50	34.72	33.87	30.50	35.43	32.82	33.29	.368	.357	9.54
Veridical Semantic Relations	1	6.83	5.28	5.87	5.38	6.52	5.92	6.00	.086	.087	3.14
	2	13.72	12.97	13.26	10.65	13.35	11.92	12.67	.195	.175	5.25
	3	16.22	18.00	17.32	15.42	19.17	17.18	17.20	.255	.253	6.79
	4	19.00	21.72	20.68	18.54	22.30	20.31	20.39	.304	.299	8.10
	R	15.72	16.31	16.09	14.23	17.13	15.59	15.85	.237	.229	6.72
Veridical Conditional Relations	1	.39	.41	.40	.08	.13	.10	.25	.033	.008	.44
	2	.61	.45	.51	.35	.52	.43	.48	.043	.036	.65
	3	.67	.76	.73	.35	.83	.58	.65	.061	.048	.78
	4	1.11	.97	1.02	.77	.96	.86	.95	.085	.072	.97
	R	.61	.72	.68	.35	.65	.49	.58	.057	.041	.73
N		18	29	47	26	23	49	96	47	49	

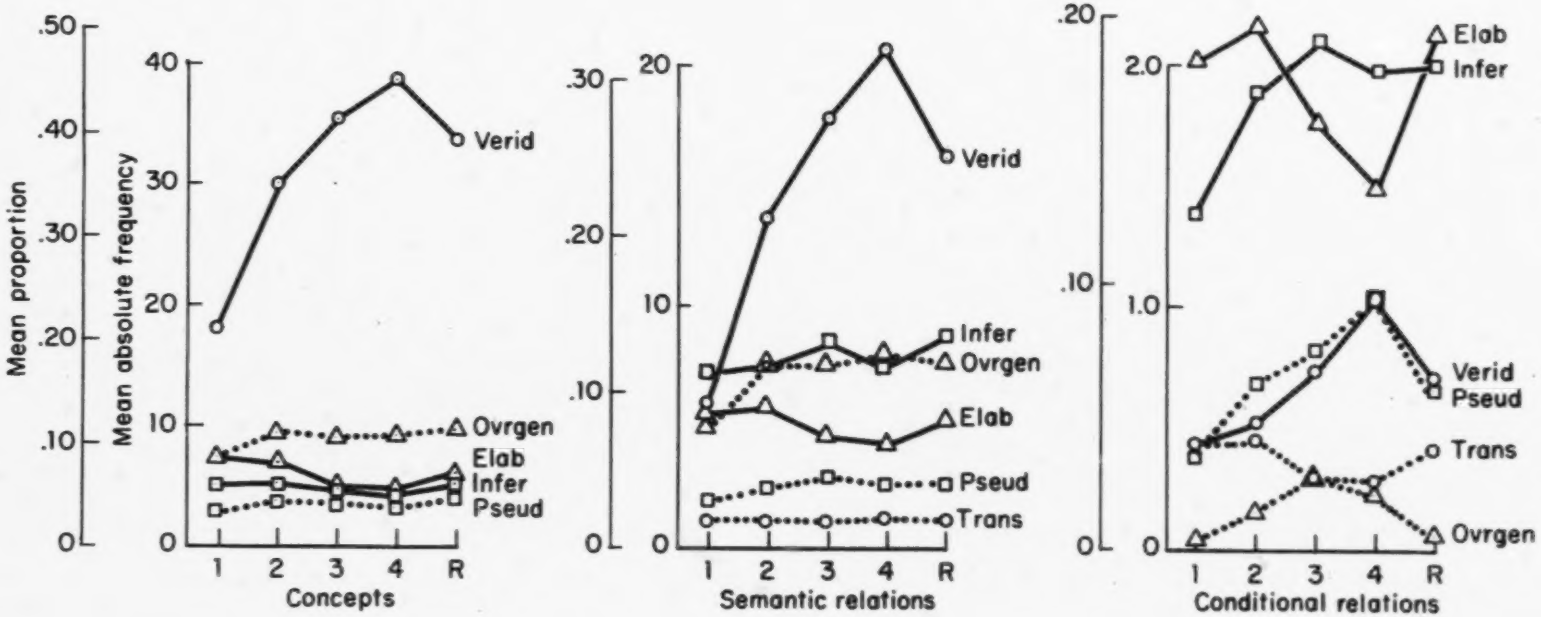


Figure 5.1

Mean Response Class Frequencies for Concepts, Semantic Relations, and Conditional Relations, trials 1 to 4 and Reminiscence, Condition A

Table 5.2

Means and Pooled Within-Group Standard Deviations of Frequencies of Overgeneralized and Pseudodiscriminated Concepts, and Semantic Relations
Conditions A and B

		Condition A			Condition B			
Response Class	Trial	male	female	pooled	male	female	pooled	Pooled Within-Group Standard Deviations
Overgeneralized Concepts	1	7.00	7.28	7.17	7.62	7.70	7.65	3.32
	2	8.11	9.97	9.26	10.04	11.43	10.69	3.31
	3	7.39	10.17	9.11	10.12	10.65	10.37	3.23
	4	8.39	10.03	9.40	9.96	11.57	10.71	3.77
	R	8.94	10.03	9.62	9.12	11.61	10.29	3.71
Overgeneralized Semantic Relations	1	4.89	5.07	5.00	4.77	5.65	5.18	2.51
	2	7.06	8.10	7.70	7.12	9.17	8.08	3.04
	3	6.28	8.24	7.49	7.42	9.04	8.18	2.93
	4	7.56	8.14	7.91	7.62	9.26	8.39	3.40
	R	7.28	8.03	7.74	7.08	9.04	8.00	3.03
Pseudo-discriminated Concepts	1	2.89	3.03	2.98	2.73	2.13	2.45	1.58
	2	3.78	3.93	3.87	3.77	3.22	3.51	1.98
	3	3.44	3.86	3.70	3.35	3.43	3.39	1.82
	4	3.00	3.48	3.30	3.58	3.35	3.47	1.56
	R	3.67	4.24	4.02	3.58	3.61	3.59	2.50
Pseudo-discriminated Semantic Relations	1	1.94	1.69	1.79	1.38	1.09	1.24	1.29
	2	2.56	2.45	2.49	2.04	1.87	1.96	1.70
	3	3.00	2.86	2.91	2.15	2.48	2.31	1.88
	4	2.33	2.62	2.51	2.42	2.22	2.33	1.37
	R	1.94	3.24	2.74	1.88	2.61	2.22	1.56
N		18	29	47	26	23	49	

Table 5.3

Means and Pooled Within-Group Standard Deviations of Frequencies of Inferred Concepts, Semantic Relations, and Conditional Relations
Conditions A and B

Response Class	Trial	Condition A male	Condition A female	Condition A pooled	Condition B male	Condition B female	Condition B pooled	Pooled Within-Group Standard Deviations
Inferred Concepts	1	5.61	5.28	5.41	5.65	5.48	5.57	2.88
	2	5.78	4.90	5.24	7.92	5.91	6.98	4.93
	3	4.78	5.52	5.24	7.73	5.26	6.57	6.06
	4	4.67	4.59	4.62	7.23	4.96	6.16	4.14
	R	5.72	5.62	5.66	9.85	5.35	7.74	8.93
Inferred Semantic Relations	1	7.33	7.17	7.23	7.73	7.30	7.53	3.64
	2	7.28	7.86	7.64	9.58	9.13	9.37	3.56
	3	7.83	8.72	8.38	9.73	9.96	9.84	3.35
	4	7.28	7.86	7.64	9.12	9.39	9.24	3.47
	R	8.33	8.79	8.62	10.46	9.57	10.04	4.03
Inferred Conditional Relations	1	1.56	1.31	1.40	1.58	.83	1.22	1.34
	2	1.72	2.00	1.89	2.27	2.09	2.18	1.68
	3	2.00	2.17	2.11	2.54	2.17	2.37	1.67
	4	1.56	2.24	1.98	2.65	2.26	2.47	1.57
	R	1.56	2.28	2.00	2.12	2.30	2.20	1.66
N		18	29	47	26	23	49	

Table 5.4

Means and Pooled Within-Group Standard Deviations of Frequencies of Elaborative Concepts, Semantic Relations, and Conditional Relations Conditions A and B

		Condition A			Condition B			Pooled Within-Group Standard Deviations
Response Class	Trial	male	female	pooled	male	female	pooled	
Elaborative Concepts	1	8.17	7.03	7.47	11.00	7.09	9.16	7.23
	2	7.17	6.86	6.98	6.50	6.70	6.59	3.14
	3	5.44	5.07	5.21	6.23	5.09	5.69	3.30
	4	5.11	4.66	4.83	4.62	4.39	4.51	3.12
	R	5.72	6.52	6.21	6.58	4.96	5.82	3.45
Elaborative Semantic Relations	1	5.78	5.62	5.68	7.77	6.30	7.08	3.40
	2	5.11	6.38	5.89	6.31	6.30	6.31	3.08
	3	4.78	4.62	4.68	5.35	4.70	5.04	3.82
	4	4.89	3.90	4.28	4.42	4.26	4.35	2.95
	R	5.17	5.45	5.34	6.19	5.00	5.63	3.15
Elaborative Conditional Relations	1	2.17	1.86	1.98	2.27	1.39	1.86	1.71
	2	1.94	2.31	2.17	2.15	1.83	2.00	1.65
	3	1.44	1.97	1.77	1.65	1.65	1.65	1.61
	4	1.11	1.72	1.49	1.81	1.96	1.88	1.47
	R	1.94	2.21	2.11	2.46	1.57	2.04	1.56
N		18	29	47	26	23	49	

and on adjustments to a resulting decrease in "information load" (Hypothesis IC), are found in Tables 5.1-5.3 and Figure 5.1. The mean frequencies of veridical concepts and semantic relations exhibit the expected negatively accelerated increase; extrapolation of the curve suggests that a great many more exposures to the discourse would be required to reach anything approaching recall of all of the explicit concepts or semantic relations contained in the text. Inspection of the changes in mean frequencies of overgeneralized concepts and relations with repeated trials of exposure to the text indicates that very little increase occurred after the second trial. Inferred relations showed a slow rate of increase without the negatively accelerated form, suggesting that the generation of inferred relations would continue to increase with still more exposures to the text. Statistical analyses of these changes were made with respect to trial effects pooled over conditions A and B and are reported in Tables 5.5-5.7. The analyses reported assess trial "main effects" within the general multivariate linear model by computing differences between successive trial scores and testing the hypothesis that the grand mean vector of difference scores (for acquisition only, i.e., for trials 1-4) is equivalent to the null vector. Univariate F's were also obtained for each successive difference, and step-down F's were obtained to determine whether successive differences (e.g., increments) are independent of differences occurring on previous trials. (The univariate tests are analagous to comparisons involving trials in the familiar "repeated measures" analysis of variance model for uncorrelated response measures.) The results (see the first three columns of Tables 5.5-5.7) indicate significant trials effects for all response classes except inferred concepts. For veridical concepts, significant increments were obtained on each trial after the first, and these increments were independent of previous increments. Significant increments occurring on trials after the second are also apparent for overgeneralized concepts and semantic relations, inferred semantic relations, and elaborative concepts and semantic relations. In general, these results are consistent with the hypotheses concerning effects of repeated exposures on processing activities in "normal" comprehension. The above results also appear to hold under contextual condition B, as expected (Hypothesis IIA).

Finally, consider the hypotheses involving changes occurring in reminiscence (Hypothesis ID). Inspection of Figure 5.1 and Tables 5.1, 5.5, and 5.6 indicates that a significant decrease in the number of veridical concepts and semantic relations did occur (Hypothesis ID1), but with the interesting result that these decrements are not independent of previously occurring increments. Thus, evidently, decrements in the amount of reproduced semantic information are predictable from the previous changes which occurred during acquisition. The correlations of the changes in frequencies of veridical concepts and semantic relations on trial 4 with changes in these frequencies on the reminiscence trial are -.574 and -.536 respectively. The correlations reported are pooled estimates based on the data obtained under both conditions A and B (i.e., pooled within-group estimates) and are significant ($p < .001$). These correlations indicate that for persons for whom the rate of increase in veridical semantic information

Table 5.5

Analyses of Variance of Inter-Trial Differences in Frequencies of Veridical, Overgeneralized, and Pseudodiscriminated Concepts Testing Trials Effect (Hypothesis that Grand Mean Vector of Difference Scores is Equivalent to Null Vector) and Effects Due to Conditions, Sex, and Interaction, Groups A and B

(a)

		Trials (Grand Mean)			Conditions		
		Univariate[1]	Step-Down	Multivariate[2]	Univariate[1]	Step-Down	Multivariate[2]
Response Class	Trials	F	F	F	F	F	F
Veridical Concepts	2-1	308.96***			1.03		
	3-2	114.62***	20.88***	149.31***	3.39	3.57	1.74
	4-3	48.15***	10.40**		.02	.61	
	R-4	79.58***	.17		1.34	.74	
Over-generalized Concepts	2-1	47.97***			2.45		
	3-2	.34	3.92	20.25***	.01	.32	.95
	4-3	.76	4.99*		.00	.13	
	R-4	.09	.18		.81	1.07	
Pseudo-discriminated Concepts	2-1	19.82***			.14		
	3-2	.46	3.44	8.05***	.05	.26	1.16
	4-3	.63	.51		1.47	3.05	
	R-4	2.19	4.17*		1.04	.04	

(b)

		Sex			Interaction		
		Univariate[1]	Step-Down	Multivariate[2]	Univariate[1]	Step-Down	Multivariate[2]
Response Class	Trials	F	F	F	F	F	F
Veridical Concepts	2-1	3.54			.69		
	3-2	3.55	2.97	2.18	1.32	1.43	.79
	4-3	.01	.01		.00	.25	
	R-4	1.42	.58		.13	.52	
Over-generalized Concepts	2-1	3.68			.03		
	3-2	.00	.78	1.57	1.16	1.57	.90
	4-3	.00	.29		2.14	1.11	
	R-4	.05	.13		.91	3.54	
Pseudo-discriminated Concepts	2-1	.00			.00		
	3-2	1.08	1.62	.59	.19	.29	.11
	4-3	.10	.15		.23	.05	
	R-4	.10	.29		.02	.00	

1. d.f. = 1,92
2. d.f. = 3,90

* = $p < .05$
** = $p < .01$
*** = $p < .001$

Table 5.6

Analyses of Variance of Inter-Trial Differences in Frequencies of Veridical, Overgeneralized, and Pseudodiscriminated Semantic Relations. Testing Trials Effect and Effects Due to Conditions, Sex, and Interaction; Conditions A and B.

(a)

		Trials (Grand Mean)			Conditions		
		Uni-variate[1]	Step-Down	Multi-variate[2]	Uni-variate[1]	Step-Down	Multi-variate[2]
Response Class	Trials	F	F	F	F	F	F
Veridical	2-1	274.13***			2.30		
Semantic	3-2	120.65***	29.26***	147.54***	3.13	3.06	1.79
Relations	4-3	60.18***	11.27**		.02	.03	
	R-4	98.02***	.15		.17	.13	
Over-	2-1	70.40***			.24		
generalized	3-2	.03	9.72**	34.84***	.45	1.02	.42
Semantic	4-3	.77	9.57**		.28	.01	
Relations	R-4	.58	3.25		.06	.22	
Pseudo-	2-1	12.76**			.00		
discriminated	3-2	3.71	12.68**	11.33***	.03	.02	.56
Semantic	4-3	.79	5.58*		1.14	1.65	
Relations	R-4	.11	4.04*		.25	.10	

(b)

		Sex			Interaction		
		Uni-variate[1]	Step-Down	Multi-variate[2]	Uni-variate[1]	Step-Down	Multi-variate[2]
Response Class	Trials	F	F	F	F	F	F
Veridical	2-1	2.07			.21		
Semantic	3-2	4.31*	4.12*	2.22	.73	.73	.46
Relations	4-3	.32	.44		.30	.46	
	R-4	2.47	.51		.44	.07	
Over-	2-1	2.27			.05		
generalized	3-2	.16	1.45	1.25	1.25	1.29	.59
Semantic	4-3	.88	.05		.94	.44	
Relations	R-4	.11	.02		.01	.65	
Pseudo-	2-1	.12			.00		
discriminated	3-2	.32	.62	.35	.42	.49	.42
Semantic	4-3	.01	.31		1.24	.76	
Relations	R-4	6.60*	12.10**		.01	.63	

1. d.f. = 1,92
2. d.f. = 3,90

* = p < .05
** = p < .01
*** = p < .001

Table 5.7

Analyses of Variance of Inter-Trial Differences in Frequencies of Inferred and Elaborative Concepts and Semantic Relations Testing Trials Effects and Effects Due to Conditions, Sex, and Interaction, Groups A and B.

(a)

		Trials (Grand Mean)			Conditions		
Response Class	Trials	Univariate[1] F	Step-Down F	Multivariate[2] F	Univariate[1] F	Step-Down F	Multivariate[2] F
Inferred Concepts	2-1	1.47			1.88		
	3-2	.59	1.03	1.91	.18	.49	1.21
	4-3	2.32	3.17		.03	1.27	
	R-4	5.14*	3.16		.15	.02	
Inferred Semantic Relations	2-1	7.68**			3.33		
	3-2	3.07	9.33**	6.01***	.10	.23	1.28
	4-3	3.86	.43		.03	.32	
	R-4	5.10*	8.90**		.09	.20	
Elaborative Concepts	2-1	4.88*			1.70		
	3-2	18.51***	21.57***	17.06***	1.72	1.15	1.19
	4-3	7.08**	18.40***		1.67	.72	
	R-4	20.33***	4.70*		.00	.51	
Elaborative Semantic Relations	2-1	.79			1.36		
	3-2	15.29***	18.33***	11.87***	.14	.51	.98
	4-3	3.24	13.66***		.36	1.08	
	R-4	11.79***	1.38		.24	.05	

(b)

		Sex			Interaction		
Response Class	Trials	Univariate[1] F	Step-Down F	Multivariate[2] F	Univariate[1] F	Step-Down F	Multivariate[2] F
Inferred Concepts	2-1	1.25			.37		
	3-2	1.10	1.65	1.26	3.54	3.18	1.29
	4-3	.21	.88		.56	.34	
	R-4	.91	1.18		.88	.17	
Inferred Semantic Relations	2-1	.19			.21		
	3-2	.49	.93	.38	.07	.01	.09
	4-3	.03	.02		.07	.05	
	R-4	.66	.41		.43	.52	
Elaborative Concepts	2-1	2.99			1.32		
	3-2	1.27	.65	1.23	1.03	.65	.73
	4-3	.48	.09		.68	.23	
	R-4	.01	.23		4.78*	3.36	
Elaborative Semantic Relations	2-1	4.70*			.00		
	3-2	2.59	1.04	2.06	.36	.40	.85
	4-3	.08	.48		1.13	2.15	
	R-4	.03	.00		2.74	.96	

1. d.f. = 1,92
2. d.f. = 3,90

* = p .05
** = p .01
*** = p .001

with repeated exposures to a discourse is high, relatively more explicit semantic information is lost in reminiscence than for persons exhibiting a smaller rate of increase during acquisition. Such a result would be expected if, say, a constant proportion of the previously acquired semantic information were lost during the retention interval. The results obtained for overgeneralized concepts and semantic relations involving overgeneralized concepts indicate that no significant increments in these frequencies occurred in reminiscence (see Figure 5.1 and Tables 5.2, 5.5, and 5.6). Thus, the data do not indicate that conceptual simplification increased in reminiscence. However, frequencies of subject-generated inferred concepts and semantic relations did increase as expected in reminiscence (Hypothesis ID3) and the observed increases were statistically significant and (for the inferred semantic relations) independent of previous increments which occurred during acquisition (cf. Tables 5.3 and 5.7). Thus there is evidence for an increase in inferentially generated semantic information in reminiscence. These results also appear to hold under both contextual conditions.

Now consider the hypotheses (involving conditions A and B) concerning process invariance and effects of contextual conditions on processing activities in the acquisition of semantic information from discourse and, hence, on semantic information resulting from these processes. In particular we will consider hypotheses involving: (IIA) contextual invariance of all results involving limits on processing capacity, adjustments to limits on processing capacity, and effects of repeated exposures to a discourse; (IIB) effects of contextual conditions on the discrimination of conceptual categories; (IIC) effects of contextual conditions on extent of generative processing; and (IID) effects of repeated exposures on context-induced differences in extent of generative processing. The results relevant to Hypothesis IIA have already been presented and indicate a rather striking degree of invariance of those aspects of the data which were interpreted either as resulting directly from those limitations on processing capacity which are encountered when a discourse is processed, or from adjustments to these limitations.

In Hypothesis IIB it was suggested that one effect of contextual condition B would be to increase the "informational load" on a subject (i.e., the sheer amount of processing required) and hence result in an increased tendency to simplify conceptual categories by overgeneralization. The relevant data are the mean frequencies of overgeneralized concepts for each contextual condition, A and B, (reported in Table 5.2) and mean frequencies of semantic relations involving overgeneralized concepts (reported in the same Table and plotted in Figure 5.2). The results indicate that differences in the predicted direction were obtained and that these differences increased slightly with repeated exposures to the text. An analysis of variance of frequencies of overgeneralized concepts (Table 5.8) indicates statistically significant main effects of contextual conditions for trials 2 and 3, but that the conditions effect on trial 3 is not independent of that obtained on trial 2. Thus, there is some evidence to indicate that the observed effects on frequencies of overgeneralized concepts to some extent are

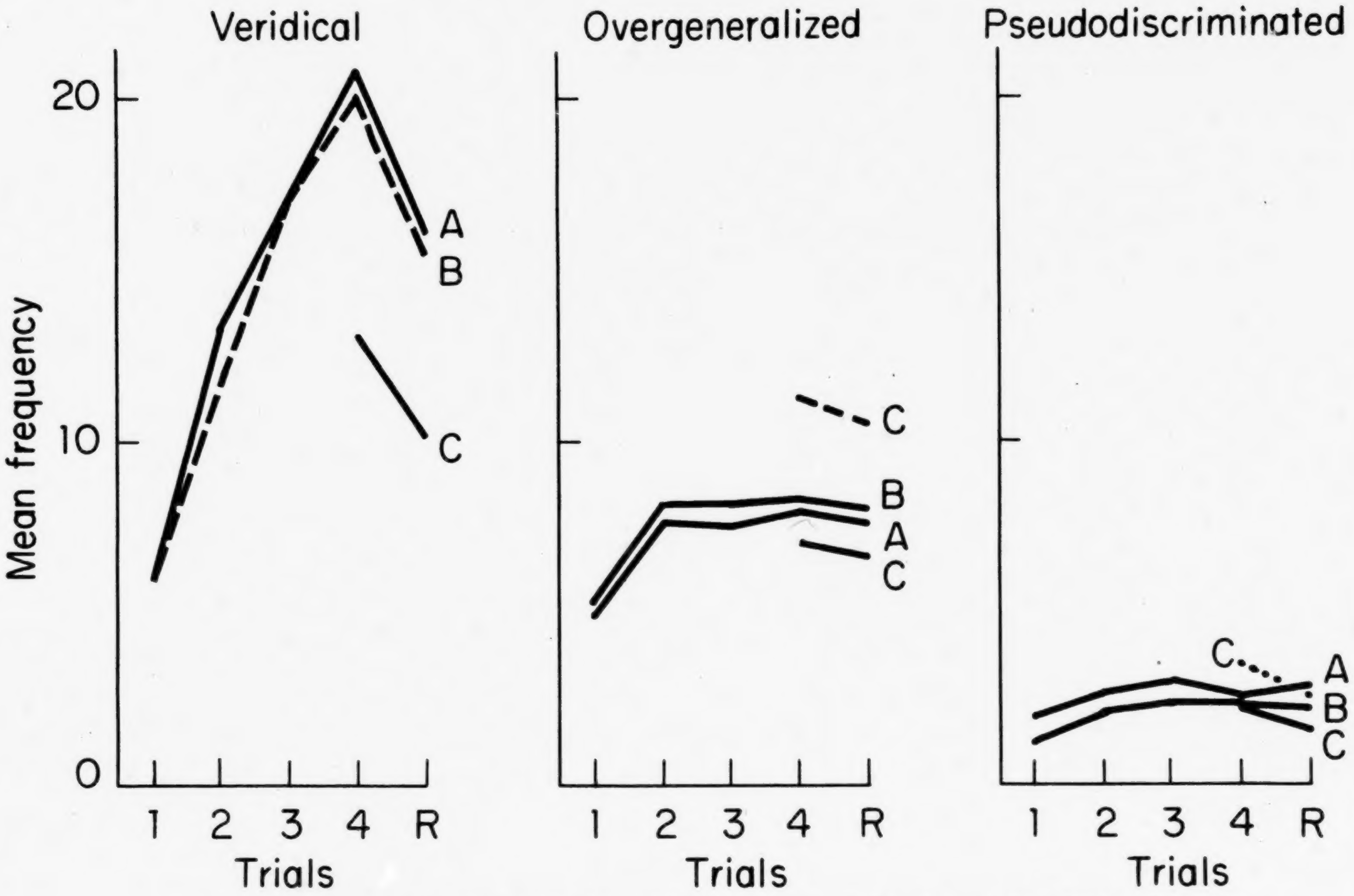


Figure 5.2 -- Mean Frequencies of Veridical, Overgeneralized, and Pseudodiscriminated Semantic Relations Obtained under Contextual Conditions A, B, and C

Table 5.8

Analyses of Variance of Frequencies of Veridical, Overgeneralized, and Pseudo-discriminated Concepts Testing Effects Due to Conditions, Sex, and Interaction, Conditions A and B

		Conditions			Sex			Interaction		
Response Class	Trial	Uni-variate[1] F	Step-Down F	Multi-variate[2] F	Uni-variate[1] F	Step-Down F	Multi-variate F	Uni-variate F	Step-Down F	Multi-variate[2] F
Veridical Concepts	1	.02			.29			2.79		
	2	.79	1.09		3.37	3.91		3.77	1.18	
	3	.11	3.46	1.19	6.77*	3.13	1.55	.88	1.10	1.08
	4	.14	.59		5.43*	.03		.68	.17	
	R	.11	.77		3.28	.42		.47	.25	
Over-generalized Concepts	1	.56			.07			.02		
	2	6.13*	5.53*		5.61*	6.03*		.11	.09	
	3	5.71*	3.18	2.11	6.13*	3.78	2.34*	2.81	2.67	1.32
	4	3.94	.86		4.32*	1.14		.00	.67	
	R	1.29	.34		5.43*	.54		.83	3.07	
Pseudo-discriminated Concepts	1	2.64			.48			1.30		
	2	.78	.19		.24	.09		.74	.31	
	3	.49	.01	.83	.45	1.12	.40	.19	.01	.48
	4	.47	1.28		.15	.08		1.22	.75	
	R	.49	.13		.34	.27		.28	.06	

1. d.f. = 1, 92
2. d.f. = 5,88

* = $p < .05$
** = $p < .01$
*** = $p < .001$

cumulative. Sex main effects are also significant, indicating a statistically reliable tendency for females to produce more overgeneralized concepts than males. This sex effect may be due in part to a tendency for the females to produce more semantic information which can be identified with information which was explicitly represented in the input text. No significant interactions of contextual conditions with sex were found. An analysis of variance of frequencies of semantic relations involving overgeneralized concepts resulted in nonsignificant main effects due to conditions, significant sex main effects on trials 2 and 3, and on the reminiscence trial, and no significant interactions. Step-down analyses of sex effects reveal that the observed differences on the reminiscence trial reflect a cumulative growth in overgeneralized semantic relations during acquisition. Analyses of variance of frequencies of semantic relations involving pseudodiscriminated concepts (Table 5.9) resulted in a significant main effect of contextual conditions on trial 1. Thus, when compared to context A, context B appears to have produced a greater tendency to reduce the amount of "conceptual" information through overgeneralization while at the same time producing a lesser tendency to overspecify conceptual classes by attaching additional self-generated information to the concepts.

Hypothesis IIC involves the effects of the problem solving context on the generation of semantic information which does not correspond to information explicitly represented in the input discourse. It was supposed that the problem solving task requires that the subject acquire only that information from the discourse which is necessary to evaluate the effects of various solution-oriented hypothetical events which the subject generates himself. These activities should result not only in selective acquisition of explicitly represented information, but should also produce more extensive inferential processing as solutions are evaluated. Thus it was expected that context B would produce increased frequencies of inferred semantic relations (and to a lesser extent, concepts). The mean frequencies of inferred concepts, semantic relations, and conditional relations for conditions A and B are presented in Table 5.3. Viridical, inferred, and elaborative semantic relations are plotted in Figure 5.3. The relevant statistical analyses are presented in Table 5.10. It is apparent that the effects of the contextual conditions on frequencies of inferred semantic relations are as predicted and increase with repeated exposures to the discourse (Hypothesis IID1). Also as predicted, these effects are more apparent for the relations than for the concepts.

Mean frequencies of elaborative concepts and semantic relations are presented in Table 5.4 (see also Figure 5.3). First, it is apparent that frequencies of elaborative elements decline with repeated exposures to the text. Thus, as more explicit and inferentially derived semantic information is acquired, there is a concomitant decrease in the generation of elaborative information. Second, while the experimental condition (B) does appear to have produced a greater number of elaborative concepts and semantic relations on trial one (Hypothesis IIC2) than were obtained under the "natural" context (A), the differences were not large enough to be statistically significant (Table 5.10). The differences between the two contexts also appear to become smaller with repeated exposures to the text. In general, contextual condition B appears to have affected

Table 5.9

Analyses of Variance of Frequencies of Veridical, Overgeneralized, and Pseudo-discriminated Semantic Relations Testing Effects Due to Conditions, Sex, and Interaction, Conditions A and B.

		Conditions			Sex			Interaction		
Response Class	Trial	Uni-variate[1] F	Step-Down F	Multi-variate[2] F	Uni-variate[1] F	Step-Down F	Multi-variate[2] F	Uni-variate[1] F	Step-Down F	Multi-variate[2] F
Veridical Semantic Relations	1	.02		1.09	.10		1.53	4.28*		1.29
	2	1.52	2.25		.79	2.14		2.51	.08	
	3	.02	3.03		3.85	4.13*		.49	.79	
	4	.00	.03		3.74	.56		.10	.96	
	R	.06	.15		1.57	.71		.69	.45	
Over-generalized Semantic Relations	1	.20		.51	1.04		2.05	.45		.67
	2	.80	.62		6.06*	4.97*		.64	.38	
	3	2.57	1.69		8.70**	3.44		.08	.80	
	4	.70	.05		2.49	.17		.57	.70	
	R	.41	.04		4.68*	.54		.92	1.03	
Pseudo-discriminated Semantic Relations	1	4.72*		1.31	1.07		2.63*	.01		.46
	2	2.40	1.31		.15	.04		.01	.01	
	3	2.48	.62		.06	.29		.35	.48	
	4	.30	.01		.02	.02		.75	.95	
	R	1.14	.04		9.74**	11.62***		.78	.84	

1. d.f. = 1, 92
2. d.f. = 5, 88

* = $p < .05$
** = $p < .01$
*** = $p < .001$

Table 5.10

Analyses of Variance of Frequencies of Inferred and Elaborative Concepts and Semantic Relations Testing Effects Due to Conditions, Sex, and Interaction, Conditions A and B

		Conditions			Sex			Interaction		
Response Class	Trial	Uni-variate^1 F	Step-Down F	Multi-variate^2 F	Uni-variate^1 F	Step-Down F	Multi-variate^2 F	Uni-variate^1 F	Step-Down F	Multi-variate^2 F
Inferred Concepts	1	.04		1.16	.18		1.10	.02		.80
	2	2.39	2.34		2.00	1.81		.30	.35	
	3	1.15	.55		.47	1.78		1.63	3.14	
	4	2.92	1.93		1.88	1.55		1.63	.36	
	R	1.08	.91		1.54	.21		1.41	.17	
Inferred Semantic Relations	1	.12		1.96	.15		.32	.03		.21
	2	5.84*	6.02*		.01	.07		.49	.46	
	3	5.09*	1.53		.65	.94		.23	.02	
	4	5.47*	1.82		.36	.06		.05	.00	
	R	3.01	.29		.07	.39		.66	.55	
Elaborative Concepts	1	.93		.86	2.83		.82	.86		1.13
	2	.41	.99		.01	.23		.15	.51	
	3	.35	.91		1.23	1.02		.32	.59	
	4	.34	.85		.28	.00		.03	.22	
	R	.24	.67		.33	.12		2.86	3.42	
Elaborative Semantic Relations	1	3.61		.78	1.33		1.36	.86		.78
	2	.77	.01		.98	3.30		.99	.36	
	3	.30	.01		.48	1.31		.18	.00	
	4	.01	.39		.89	.85		.46	1.50	
	R	.20	.00		.49	.05		1.27	1.19	

1. d.f. = 1,92
2. d.f. = 5,88

* = $p < .05$

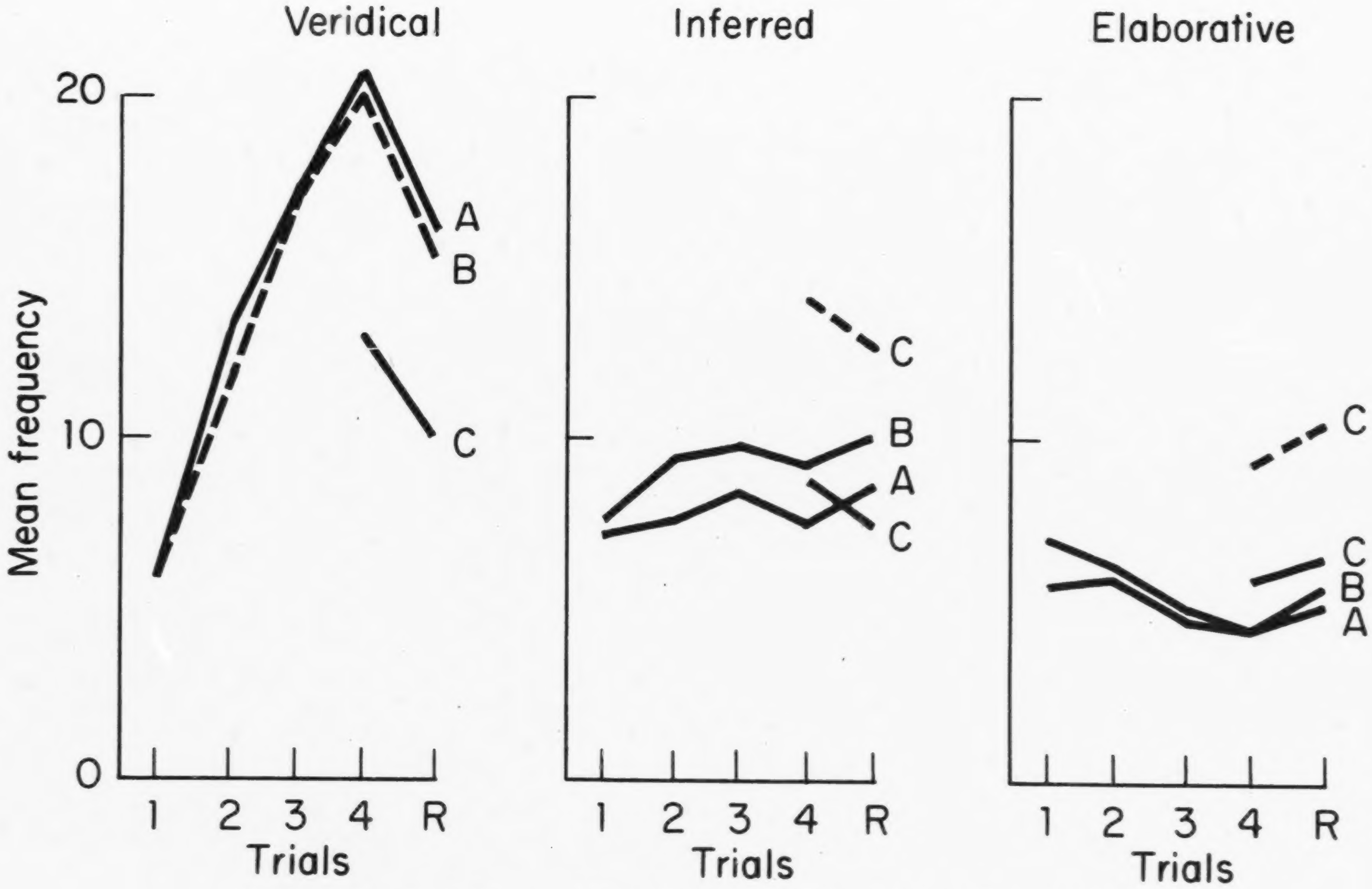


Figure 5.3 -- Mean Frequencies of Veridical, Inferred, and Elaborative Semantic Relations Obtained under Contextual Conditions A, B, and C

the types and extent of semantic information acquired, (1) by inducing different degrees of "information load" on the subjects (and hence adjustments to such load), and (2) by inducing inferential operations on semantic information acquired from the discourse. Since the generation of elaborative elements may reflect a relatively unsuccessful attempt to reconstruct explicit information from previously acquired information which is incomplete as well as a generative process occurring as a discourse is received, the presence of elaborative elements in a subject's recall protocol may reflect processes other than (or in addition to) those indicated in Hypothesis IIC2. A similar ambiguity of course, also occurs in interpreting inferred semantic elements. Thus, if it were possible to demonstrate that generative operations actually occurred during input, it would then be extremely unlikely that the experimental outcomes described above, could be due solely to events occurring during output (i.e. during reconstruction of knowledge acquired from the essay)--events which are in fact unrelated to the explanations presented in the hypotheses. This question will be investigated in the next chapter.

Finally, consider the hypotheses (involving all three conditons, A, B and C) concerning the effects of the incidental memory condition on the generation of inferred and elaborative concepts and semantic relations, on the simplification of conceptual categories, and on the extent of veridical information acquired. Mean frequencies of conceptual response classes for all three conditions on trial 4 and reminiscence are reported in Table 5.11 and mean frequencies for classes of semantic relations are reported in Table 5.12. Means are also plotted in Figures 5.2 and 5.3. Analyses of variance of all scores are presented in Table 5.13. First, observe that, as expected, smaller frequencies of veridical concepts and semantic relations were obtained for condition C, indicating selectivity in the acquisition and long-term storage of explicitly coded semantic information. Since the incidental memory task requires only that the subject acquire information relevant to problem solution, it is reasonable to expect not only selectivity in information acquired, but also that relatively more information will be acquired in a generative manner. Thus, a subject's investigation of the consequences of an hypothetical solution may induce him to deduce additional facts about the island from the information which was given in the essay. Thus, measured relative to the extent of veridical information acquired, relative frequencies of inferred and elaborative elements should be greater than those obtained under condition B and much greater than those obtained under condition A (Hypotheses IIIA and IIIB). The relative frequency data clearly support these hypotheses. For elaborative semantic relations, statistically significant effects of conditions were obtained even for the absolute frequency measure, and the absolute frequency of inferred relations under condition C on trial 4 is higher than that obtained under condition A. Thus, the data are in agreement with the predictions of hypotheses IIIA and IIIB: the relative extent of inferentially generated and other self-generated semantic information is drastically increased in the incidental memory condition. While there may be an ambiguity as to whether observed inferred or elaborative elements reflect processes occurring at input or processes occurring at output, it is hard to explain how, if inferential processes occurred solely during recall, frequencies of inferred elements could increase and occur with such high relative frequencies. No significant sex differences or conditions by sex interations

Table 5.11

Mean Absolute and Relative Frequencies of Veridical, Overgeneralized, Pseudodiscriminated, and Elaborative Concepts, Conditions A, B, and C, Trial 4 and Reminiscence Trial

		Condition A			Condition B			Condition C			Mean Relative Frequency Condition		
Response Class	Trial	male	female	pooled	male	female	pooled	male	female	pooled	A	B	C
Veridical Concepts	4	36.72	40.00	38.74	35.73	42.61	38.96	27.64	31.70	29.71	38.74	38.74	38.74
	R	32.50	34.72	33.87	30.50	35.43	32.82	22.77	27.00	24.93	33.87	33.87	33.87
Overgeneralized Concepts	4	8.39	10.03	9.40	9.96	11.56	10.71	8.45	9.83	9.16	9.40	10.66	11.94
	R	8.94	10.03	9.62	9.12	11.61	10.29	7.91	8.61	8.27	9.62	10.62	11.23
Pseudodiscriminated Concepts	4	3.00	3.48	3.30	3.58	3.35	3.47	3.00	3.61	3.31	3.30	3.42	4.32
	R	3.67	4.24	4.02	3.58	3.61	3.59	2.09	3.48	2.80	4.02	3.71	3.80
Inferred Concepts	4	4.67	4.59	4.62	7.23	4.96	6.16	5.05	6.00	5.53	4.62	6.36	7.21
	R	5.72	5.62	5.66	9.85	5.35	7.73	5.27	4.91	5.09	5.66	7.98	6.64
Elaborative Concepts	4	5.11	4.66	4.83	4.62	4.39	4.51	6.41	5.74	6.07	4.83	4.49	7.92
	R	5.72	6.52	6.21	6.58	4.96	5.82	7.27	7.26	7.27	6.21	6.01	9.88
N		18	29	47	26	23	49	22	23	45		Total N = 141	

Table 5.12

Mean Absolute and Relative Frequencies of Veridical, Overgeneralized, Pseudodiscriminated, Inferred, and Elaborative Relations; Trial 4 and Reminiscence Trial, Conditions A, B, and C

		Mean Absolute Frequencies									Mean Relative Frequencies		
		Condition A			Condition B			Condition C			Condition		
Response Class	Trial	male	female	pooled	male	female	pooled	male	female	pooled	A	B	C
Veridical Semantic Relations	4	19.00	21.72	20.68	18.54	22.30	20.31	11.91	14.96	13.47	20.68	20.68	20.68
	R	15.72	16.31	16.09	14.23	17.13	15.59	9.68	11.17	10.44	16.09	16.09	16.09
Overgeneralized Semantic Relations	4	7.56	8.14	7.91	7.62	9.26	8.39	6.86	7.57	7.22	7.91	8.54	11.08
	R	7.28	8.03	7.74	7.08	9.04	8.00	6.09	7.39	6.76	7.74	8.26	10.38
Pseudodiscriminated Semantic Relations	4	2.33	2.62	2.51	2.42	2.22	2.33	2.23	2.22	2.22	2.51	2.37	3.41
	R	1.94	3.24	2.74	1.88	2.61	2.22	1.41	1.87	1.64	2.74	2.29	2.52
Inferred Semantic Relations	4	7.28	7.86	7.64	9.12	9.39	9.24	8.68	9.17	8.93	7.64	9.41	13.96
	R	8.33	8.79	8.62	10.46	9.57	10.04	7.05	8.43	7.76	8.62	10.36	12.26
Elaborative Semantic Relations	4	4.89	3.90	4.28	4.42	4.26	4.35	6.45	5.35	5.89	4.28	4.43	9.21
	R	5.17	5.45	5.34	6.19	5.00	5.63	6.14	6.91	6.53	5.34	5.81	10.33
N		18	29	47	26	23	49	22	23	45	Total N = 141		

Table 5.13

Analyses of Variance of Response Class Frequencies,
Trial 4 and Reminiscence, Conditions A, B, and C

Response Class	Trial	Univariate F			Step-Down F			Univariate F: Difference Scores			
		Conditions^1	Sex^2	Inter-action^1	Conditions^1	Sex^2	Inter-action^1	Trials^2	Conditions^1	Sex^2	Inter-action^1
Concepts:											
Veridical	4	12.94***	7.90**	.43				101.95***	.85	.79	.34
	R	12.95***	6.00*	.27	1.86	.13	.23				
Over-generalized	4	2.87	5.89*	.02				1.27	1.04	.03	.62
	R	3.72*	5.03*	.75	2.21	1.44	.89				
Pseudodis-criminated	4	.23	1.07	.91				.31	2.53	.73	.21
	R	3.08*	2.92	1.04	3.16*	2.41	.80				
Inferred	4	1.84	.55	2.33				3.41	2.02	2.08	.61
	R	1.46	1.69	1.29	3.05	1.52	.66				
Elaborative	4	2.85	.64	.05				25.04***	.01	.11	2.40
	R	2.29	.22	1.43	.39	.00	2.57				
Semantic Relations:											
Veridical	4	13.20***	6.26*	.06				113.89***	1.80	3.76	.22
	R	11.36***	2.42	.40	.66	.44	.52				
Over-generalized	4	1.61	3.02	.37				1.37	.08	.38	.04
	R	2.63	7.72**	.53	1.52	5.12*	.31				
Pseudodis-criminated	4	.41	.01	.39				.90	1.86	7.06**	.30
	R	4.82**	10.90**	.94	4.42*	11.16**	.80				
Inferred	4	2.88	.55	.02				.49	4.42*	.04	.85
	R	4.63*	.26	1.15	4.98**	.04	1.29				
Elaborative	4	3.18*	1.74	.28				13.10**	.43	1.59	2.56
	R	1.77	.01	1.21	.36	.42	2.41				

1. d.f. = 2,135
2. d.f. = 1,135

* = $p < .05$
** = $p < .01$
*** = $p < .001$

were found for measures of inferred or elaborative semantic elements. Relative frequencies of overgeneralized concepts and relations involving overgeneralized concepts also appear to be greater for condition C than for either other condition (Hypothesis IIIC).

The changes in reminiscence produced by condition C appear to be different from the changes produced by the other two conditions with respect to frequencies of inferred semantic relations. For context C there is a decrease in the number of inferred semantic relations in reminiscence, while for conditions A and B there is an increase in reminiscence (see Figure 5.3 and Table 5.12). An analysis of variance of reminiscence - trial 4 differences indicates a significant effect of conditions and a step-down analysis of absolute frequencies indicates that differences on the reminiscence trial are independent of differences on trial 4 (Table 5.13). This interesting result implies that the use of inferential processes to retrieve or reconstruct semantic information which has become less available after a long retention interval, while it does occur in situations in which the subject's semantic model is likely to consist predominately of viridical semantic information, does not occur in contexts in which the subject's semantic model contains a large proportion of inferentially generated material. Thus information processing heuristics used to retrieve or reconstruct previously acquired semantic information appear to reflect the processing events which occurred during acquisition!

It remains to examine data which reflect the acquisition of the verbatim concepts which were embedded in the discourse presented to the subjects. Two response classes will be considered: complete verbatim concepts and incomplete verbatim concepts in which verbatim information is missing from the subject's response. Mean frequencies of complete and incomplete verbatim concepts are reported in Table 5.14 for all three conditions. Analyses of variance for conditions A and B are presented in Table 5.15; analyses for all three groups are presented in Table 5.16. Consider first the acquisition data (trials 1-4) for groups A and B. A highly significant trials effect (multivariate F (3,90) = 131.11) and significant step-down F's for trial-by-trial difference scores indicate that cumulative learning of verbatim concepts occurred. In addition, the verbatim measures are the only measures in which significant interactions of conditions with sex were found. However, when complete and incomplete verbatim concepts are pooled, sex differences disappear. A similar situation appears to hold for the reminiscence trial. Thus, if accuracy is discounted, the acquisition and retention of verbatim information is unaffected by the contextual conditions. Condition C, on the other hand, produced a significant main effect on the acquisition of complete verbatim concepts but the effect on reminiscence scores is not independent of the differences produced during acquisition. These last results involving condition C would appear to reflect the process of selection of relevant information which was observed previously.

Table 5.14

Mean Frequencies of Verbatim Concepts, Conditions A, B, and C,

Trials 1-4 and Reminiscence

		Condition A			Condition B			Condition C		
Response Class	Trial	males	females	pooled	males	females	pooled	males	females	pooled
Complete	1	5.11	4.48	4.72	4.12	4.48	4.29			
	2	7.61	7.24	7.38	7.12	7.17	7.14			
	3	9.22	9.14	9.17	9.08	9.26	9.16			
	4	9.17	10.38	9.91	10.42	9.78	10.12	7.18	6.09	6.62
	R	8.50	8.76	8.66	7.85	8.22	8.02	5.91	5.87	5.89
Incomplete	1	1.22	1.07	1.13	1.19	1.00	1.10			
	2	1.56	1.55	1.55	1.58	2.48	2.00			
	3	1.28	1.83	1.62	2.19	1.96	2.08			
	4	2.17	1.48	1.74	1.62	2.09	1.84	1.82	1.87	1.84
	R	2.22	1.79	1.96	1.96	2.22	2.08	1.23	1.52	1.38
N		18	29	47	26	23	49	22	23	45

Table 5.15

Analysis of Variance of Frequencies of Verbatim Concepts,

Conditions A and B, Trials 1-4 and Reminiscence

Response Class	Trial	Conditions Uni-variate[1] F	Conditions Step-Down F	Conditions Multi-variate[2] F	Sex Uni-variate[1] F	Sex Step-Down F	Sex Multi-variate[2] F	Interaction Uni-variate[1] F	Interaction Step-Down F	Interaction Multi-variate[2] F	Trials Uni-variate[1] F	Trials Step-down F	Trials Multi-variate[3] F
Complete													
	1	1.57			.11			1.54					
	2	.33	.00	1.38	.10	.03	.20	.19	.05	2.29			
	3	.00	.56		.01	.24		.05	.10				
	4	.27	1.18		.21	.52		2.17	7.75**				
	R	.88	3.50		.24	.09		.01	1.82				
Incomplete													
	1	.05			.65			.01					
	2	3.30	3.46	1.28	2.96	3.40	.86	3.01	3.09	3.02*			
	3	4.14*	2.67		.37	.07		2.35	3.66				
	4	.01	.26		.13	.15		3.93	7.91**				
	R	.05	.00		.06	.13		.91	.01				
Inter-Trial Differences													
Complete	2-1	.23			.00			.39			153.41***		
	3-2	.45	.64	.71	.26	.26	.26	.04	.12	2.87*	91.76***	61.06***	131.11***
	4-3	.71	1.26		.34	.53		6.84*	8.07**		18.31***	18.43***	
	R-4	4.17*	2.76		.00	.13		4.69	1.34		57.05	2.57	
Incomplete	2-1	2.80			3.95*			2.28			18.77***		
	3-2	.02	1.13	1.63	.82	.00	1.38	6.91*	4.54*	4.91**	.21	6.94**	9.61***
	4-3	2.56	.95		.72	.27		9.82**	7.35**		.17	1.70	
	R-4	.02	.08		.00	.17		.37	.00		1.45	2.75	

1. def. = 1,92
2. def. = 5,88
3. def. = 3,90

* = P < .05
** = P < .01
*** = P < .001

Table 5.16

Analyses of Variance of Frequencies of Verbatim Concepts,

Conditions A, B, and C, Trial 4 and Reminiscence

		Univariate F			Step-Down F			Univariate F: Difference Scores			
Response Class	Trial	Conditions[1]	Sex[2]	Interaction[1]	Conditions[1]	Sex[2]	Interaction[1]	Trials[2]	Conditions[1]	Sex[2]	Interaction[1]
Incomplete											
	4	.00	.05	2.05							
	R	2.78	.02	.74	3.10*	.06	.25	.00	2.35	.10	.28
Complete											
	4	19.98***	.12	2.00							
	R	11.32***	.16	.06	2.18	.97	2.02	62.44***	5.06**	1.10	3.44*

1. def. = 2,135
2. def. = 1,135

* = P < .05
** = P < .01
*** = P < .001

CHAPTER 6

A QUANTITATIVE INVESTIGATION OF SOME ALTERNATIVE PROCESS MODELS

6.1 Introduction

The results which were presented in the previous chapter were found to be generally consistent with a view of discourse comprehension as a process which normally involves inferring a speaker's semantic structural knowledge from linguistic inputs which occur with such rapidity that complete interpretive processing is rendered impossible. It was also found that the extent of such generative processing may reflect contextual conditions as well as semantic properties of the discourse itself. However, there was found to be one source of ambiguity in these results, an ambiguity which, if resolved, could significantly increase the weight of evidence in favor of a generative as opposed to an interpretive view of the process of knowledge acquisition from discourse. The ambiguity in question involves the temporal locus and function of generative operations in discourse comprehension. Since all semantic measures were obtained from recall protocols, measures which reflect inferential or elaborative processing can represent results of either generative processing operations occurring at input (as a discourse is received) or those occurring at output. One purpose of the present chapter is to attempt to resolve this ambiguity by means of quantitative investigation of the multi-occassion intercorrelations of frequencies of veridical, inferred, and elaborative relations. The method involves, first, assuming that all new explicitly represented information which is acquired, is acquired during the presentation of the discourse (i.e. during input). Second, given this assumption, the interpretive processing model and generative processing models are shown to lead to different conclusions with respect to the sources of observed stochastic growth of inferred and elaborative relational structures. Third, each of these conclusions is converted into a mathematical model which expresses precisely the quantitative outcome associated with each process model. Finally, each of the alternative mathematical models is fit to the matrix of multi-trial intercorrelations of veridical, inferred, and elaborative relations and a statistical measure of goodness-of-fit is obtained. The fits of the alternative models are then compared.

A second purpose of the present chapter is to investigate questions concerning process independence, e.g. concerning the extent to which the processing operations involved in generating inferred structural elements are independent of those involved in acquiring explicitly coded semantic information. Thus, if there are inferential processing operations which are involved in generating inferred semantic information and which are not involved in acquiring explicitly coded information, then these generative processing operations ought not to be statistically dependent on the occurrence of interpretive processes. Put another way, the acquisition of an explicitly coded relation requires the first four levels of processing identified in Figure 4.2 (phonetic interpretation, generation of a surface structure, parsing, and semantic interpretation); the acquisition of an inferred relation requires an additional level of processing (generation of a new element of semantic structure), the occurrence of which ought to be independent of the previous sequence of processing events. In terms of data consisting of observed frequencies of veridical and inferred relations, these two response classes both result from similar interpretive processing operations which they have in common, but the inferred relations also result from certain generative processing operations. In factor analytic terms, measures of veridical and inferred relations should share a common (general) factor, while there should be an additional factor common only to measures of inferred relations, a factor which is uncorrelated with the general factor.

In the previous chapter the mean frequencies of various classes of response obtained from the semantic analysis of subjects' recall protocols were studied; in this chapter the statistical dependence structure of these response measures will be studied by fitting stochastic models to the matrix of intercorrelations of certain of the measures: frequencies of veridical, inferred, and elaborative semantic relations. The models which are investigated were designed to investigate both of the above questions: questions concerning process independence and concerning alternative sources of observed stochastic growth. The chapter will begin by describing four alternative stochastic growth models which will be studied and each of which is related to different assumptions concerning the processes which generated the data. It will then show how these models relate to the question, "Do generative processes occur at input?" Results obtained from fitting each of the four models then will be presented to ascertain which model best accounts for the data. Finally, results concerning the effects of the contextual conditions on the goodness-of-fit of alternative models will be presented.

6.2 Simplex models and Alternative Sources of Stochastic Growth

The models which will be described in this section were designed to investigate alternative sources of correlated growth in multiple response measures which are observed simultaneously at successive points in time. The data to which models are fit are within-group (or pooled within-group) multimeasure multi-occasion correlation matrices based on measurements of veridical, inferred, and elaborative semantic relations obtained from the analysis of subjects' written reconstructions of knowledge acquired in comprehending and remembering information presented in texts. Recall that repeated measurements were obtained from written protocols obtained after each of four exposures to the discourse. The models will be fit to investigate possible alternative explanations of observed growth in certain measure types which may result from more than one level of processing. Thus, if a measure involves additive effects, associated with two levels of information processing, observed growth in the measure may be due to (1) growth in one effect, (2) growth in the other effect, or (3) independent growth in both effects. In addition, these effects may be the result of processing operations which may be either independent or dependent. The models fit have two levels. The first level involves either (a) growth properties of each constituent effect represented by Markov simplex growth models or (b) constant effects not representing a process of stochastic growth represented by Spearman models (c.f. Jöreskog, 1970a, b). The second level involves the combination of effects which are hypothesized to account for the dependence of one set of semantic response measures on another. For example, one might assume complete independence: that there are no effects common to different classes of response, or alternatively a hierarchical model: that there is one process common to measures of veridical, inferred, and elaborative relations, that there is a second additive effect representing results of inferential processing which is common to measures of inferred and elaborative relations, and that there is a third additive effect representing "unconstrained generative processing" (elaboration) which is present only for the measures of elaborative relations. By fitting models which make assumptions at both of these levels, it will be possible to simultaneously investigate questions of process independence and of alternative sources of observed stochastic growth.

The specific questions to be answered relate to: (1) determining whether the production of veridical, inferred, and elaborative structures can each be considered to be a growth process, or, alternatively, determining whether the observed growth in inferred and elaborative structure are due to growth in the veridical (simply encoded or interpreted) structure; (2) determining whether there are distinct and mutually independent processes associated with the development of these structures; and (3) determining which hypothesis, the interpretive or the generative, best accounts for the growth properties of the data. Four models, each of which represents specific assumptions in relation to questions (1) and (2) will now be described. Then the relationship of each model to the theoretical issue (question 3) will be specified.

The above related questions will be investigated empirically using the available correlation matrix by expressing the various assumptions quantitatively as models involving both additive effects of factors associated with interpretive, inferential, and elaborative processes, and Markov simplex growth properties for certain of the additive factors (c.f., Jöreskog, 1969, 1970a). Table 6.1 contains pooled within-group estimates of the multi-occasion correlations of response class frequencies of veridical, inferred, and elaborative semantic relations obtained under conditions A and B. Inspection of Table 6.1 suggests that the intercorrelations of the veridical relations measured on trials 1 to 4 may represent a simplex (c.f. Chapter 3); similarly the intercorrelations of the counts of inferred and elaborative relations on trials 1 to 4 may also each have this property. Note that the correlations of veridical relations with inferred relations and the correlations of inferred with elaborative relations appear to vary about zero. The correlations of veridical relations with elaborative relations appear to become negative as the trials progress. Empirically, one possibility stated in the two questions raised above may be expressed quantitatively by means of the mathematical model stated formally in Table 6.2. This model supposes that (1) counts of veridical relations represent the results of a process of semantic interpretation ("encoding process") which is a stochastic

Table 6.1

Pooled Within-Group Multi-Occasion Intercorrelations of Response Class Frequencies Based on Veridical, Inferred, and Elaborative Semantic Relations

Variate																
	Response Class	Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Veridical Relations	1														
2	Veridical Relations	2	.663													
3	Veridical Relations	3	.532	.789												
4	Veridical Relations	4	.526	.739	.863											
5	Veridical Relations	R	.457	.694	.821	.822										
6	Inferred Relations	1	.223	.297	.267	.240	.265									
7	Inferred Relations	2	.005	.047	.063	.051	.013	.379								
8	Inferred Relations	3	-.029	.119	.083	.101	.076	.338	.524							
9	Inferred Relations	4	-.250	-.123	-.181	-.165	-.185	.242	.275	.526						
10	Inferred Relations	R	-.064	.039	.041	-.024	.004	.451	.304	.483	.484					
11	Elaborative Relations	1	-.140	-.118	-.176	-.149	-.128	.159	.049	.157	.217	.230				
12	Elaborative Relations	2	-.388	-.385	-.368	-.352	-.270	-.026	-.126	-.082	.105	.081	.512			
13	Elaborative Relations	3	-.192	-.336	-.305	-.263	-.279	-.146	-.175	-.110	.113	-.031	.262	.448		
14	Elaborative Relations	4	-.275	-.334	-.288	-.419	-.339	-.059	-.107	-.097	-.063	.035	.253	.390	.458	
15	Elaborative Relations	R	-.255	-.335	-.314	-.380	-.370	.055	-.072	-.057	.135	.065	.286	.336	.456	.395

Table 6.2

Summary of Model for Veridical, Inferred, and Elaborative Relations: Hierarchical Additive Encoding, Inference, and Elaborative Production Processes which are Nonstationary Markov Simplex Growth Processes

Structural Model (a)*

$$X_{tij} = \mu_{ti} + \beta_{ti}^{(G)} G_{tj} + \beta_{ti'}^{(I)} I_{tj} + \beta_{ti''}^{(E)} E_{tj} + \varepsilon_{ti'j}$$

$$G_{t+1,j} = \alpha_{t+1}^{(G)} G_{tj} + g_{t+1,j} + \varepsilon_{t+1,j}$$

$$I_{t+1,j} = \alpha_{t+1}^{(I)} I_{tj} + h_{t+1,j}$$

$$E_{t+1,j} = \alpha_{t+1}^{(E)} E_{tj} + e_{t+1,j}$$

Assumptions (b)#

1. Scaling Assumptions

$$\sum_j N_j E(G_{tj}) = \sum_j N_j E(I_{tj}) = \sum_j N_j E(E_{tj}) = E(\varepsilon_{ti'j}) = E(\varepsilon_{tj}) = 0$$

$$\mathrm{var}(g_{tj}) = \mathrm{var}(I_{tj}) = \mathrm{var}(E_{tj}) = 1$$

$$\mathrm{var}(\varepsilon_{ti'j}) = \theta^2_{ti'}$$

2. Quasi-Simplex Model: Encoding

$$\mathrm{var}(G_{tj}) = \phi_t = 1 - \psi_t^2 = 1 - \mathrm{var}(\varepsilon_{tj})$$

$$\mathrm{var}(\underline{G}) = \Gamma^{(G)} = D_\xi^{(G)}\, T\, \Phi^{(G)*}\, T' D_\xi^{(G)} + \Psi^2$$

where $\Phi^{(G)} = D_\xi^{(G)} \Phi^{(G)*} D_\xi^{(G)}$

$D_\xi^{(G)}$ is a diagonal matrix containing $\xi_t^{(G)} = \alpha_1^{(G)} \alpha_2^{(G)} \ldots \alpha_t^{(G)}$

---

* $i = 1,2,3$, (response class); $i' = 2,3$; $i'' = 3$; $t = 1, \ldots, 4$ (trials); $j = 1,2$ (group)

# For maximum likelihood estimation, it is assumed in addition that $\underline{X}$ is distributed multinormal with mean vector $\underline{\mu}_j$ and covariance matrix Σ. (Note, a lower case letter underlined indicates a column vector.)

Table 6.2 (continued)

T is a lower triangular matrix of ones.

$\Phi^{(G)}$ contains $\phi_t = 1 - \psi_t^2$ (a diagonal matrix)

Ψ^2 is a diagonal matrix containing ψ_t^2

$\underline{G}' = (G_1, G_2, G_3, G_4)$

3. Simplex Model: Inference

$$\text{var}(\underline{I}) = \Gamma^{(I)} = D_\xi^{(I)} T \, \Phi^{(I)*} \, T' D_\xi^{(I)}$$

where $D_\xi^{(I)}$ is a diagonal matrix containing $\xi_t^{(I)} = \alpha_1^{(I)} \alpha_2 \ldots \alpha_t^{(I)}$

$\underline{I}' = (I_1, I_2, I_3, I_4)$, and $\Phi^{(I)} = D_\xi^{(I)} \, \Phi^{(I)*} \, D_\xi^{(I)}$

4. Simplex Model: Elaborative Production

$$\text{var}(\underline{E}) = \Gamma^{(E)} = D_\xi^{(E)} T \, \Phi^{(E)*} \, T' \, D_\xi^{(E)} \quad \text{as in (3.)}$$

5. Additive Hierarchical Model

$$\Sigma = \text{var}(\underline{X}) = B \Gamma B' + \Theta^2$$

where

$$B = \begin{array}{c|cccccccccccccc}
 & & & & & & & & & & & & & \multicolumn{3}{c}{\text{reminiscence trials}} \\
 & G_1 & G_2 & G_3 & G_4 & I_1 & I_2 & I_3 & I_4 & E_1 & E_2 & E_3 & E_4 & 5 & 10 & 15 \\
\hline
1 & \beta_{11}^{(G)} & & & & & & & & & & & & & & \\
2 & & \beta_{21}^{(G)} & & & & & & & & & & & & & \\
3 & & & \beta_{31}^{(G)} & & & & & & & & & & & & \\
4 & & & & \beta_{41}^{(G)} & & & & & & & & & & & \\
5 & & & & & & & & & & & & & 1 & & \\
6 & \beta_{12}^{(G)} & & & & \beta_{12}^{(I)} & & & & & & & & & & \\
7 & & \beta_{22}^{(G)} & & & & \beta_{22}^{(I)} & & & & & & & & & \\
8 & & & \beta_{32}^{(G)} & & & & \beta_{32}^{(I)} & & & & & & & & \\
9 & & & & \beta_{42}^{(G)} & & & & \beta_{42}^{(I)} & & & & & & & \\
10 & & & & & & & & & & & & & & 1 & \\
11 & \beta_{13}^{(G)} & & & & \beta_{13}^{(I)} & & & & \beta_{13}^{(E)} & & & & & & \\
12 & & \beta_{23}^{(G)} & & & & \beta_{23}^{(I)} & & & & \beta_{23}^{(E)} & & & & & \\
13 & & & \beta_{33}^{(G)} & & & & \beta_{33}^{(I)} & & & & \beta_{33}^{(E)} & & & & \\
14 & & & & \beta_{43}^{(G)} & & & & \beta_{43}^{(I)} & & & & \beta_{43}^{(E)} & & & \\
15 & & & & & & & & & & & & & & & 1
\end{array}$$

(blanks are zeros)

Table 6.2 (continued)

6. Assumption of Independent Processes

$$\Gamma = \left\| \begin{array}{cccc} \Gamma^{(G)} & 0 & 0 & \mathrm{cov}(\underline{G}, \underline{X}_R) \\ & \Gamma^{(I)} & 0 & \mathrm{cov}(\underline{I}, \underline{X}_R) \\ & & \Gamma^{(E)} & \mathrm{cov}\ (\underline{E}, \underline{X}_R) \\ & & & \mathrm{var}\ (\underline{X}_R) \end{array} \right\| \quad \text{(A Symmetric Matrix)}$$

Θ^2 is a diagonal matrix containing Θ^2_{ti}

$\underline{X}$ is a vector of response class frequencies ordered as in Table 4,

$\underline{X}'_R = (X_5, X_{10}, X_{15})$

growth process (more explicitly a nonstationary Markov process with continuous states), (2) counts of inferred relations reflect a linear combination of the results of the encoding process and a process of inference which is a stochastic growth process independent of encoding, and (3) that counts of elaborative relations reflect a linear combination of the results of encoding, inference, and an elaborative process which is a stochastic growth process independent of encoding and inference. The fifth "reminiscence" trial measures are treated as "extension" variables: i.e., their correlations with the latent variables encoding, inference, and elaborative production are estimated as a part of the model. The first equation in Table 6.2 states that the frequency of response class i on trial t for context j is equal to the mean for that measure-trial combination (μ_{ti}) plus linear regression on encoding at trial t for context j (G_{tj}) plus (for inferred and elaborative relations) linear regression on inference at trial t for context j (I_{tj}) plus (solely for elaborative relations) linear regression on elaborative production at trial t for context j (E_{tj}). The last term of this equation ($\varepsilon_{ti'j}$) represents a measure-specific error component. The next three equations of the structural model represent the growth property defined respectively for encoding, inference, and elaborative production. The remaining equations express assumptions which are necessary to completely specify the model including (1) arbitrary scaling assumptions, (2)-(4) assumptions defining the simplex growth models, and (5) assumptions which complete the definition of the additive hierarchical model described above.

The above model, Model IV, is one of four models fit to the correlation matrix of Table 6.1 each of which reflects different assumptions about the processes underlying the observed data. As does Model IV, Models I and II both assume that all three response classes reflect an encoding process which is stochastically increasing. However, unlike Model IV, Models I and II both assume (1) that the observed counts of inferred and elaborative relations (additively) reflect inferential or elaborative processes respectively in addition to the encoding process, and (2) that neither of these processes has stochastic growth properties. Models I and II differ with regard to the assumed dependence (Model I) or independence (Model II) of the constituent encoding, inferential, and elaborative processes. Model III is similar to Model IV but does not allow for inferred elements to enter into counts of elaborative relations. Models I and II are similar to Model III in this respect. In summary: Model I assumes an encoding process which is stochastic, inferred and elaborative processes which are stationary Spearman cases (i.e. growth in inferred and elaborative relations is due solely to growth in the encoded structure), and all processes are dependent; Model II is identical to Model I except all processes are independent; and Models III and IV assume independent stochastic growth processes associated with encoding, inference, and elaborative production respectively.

6.3 Do Generative Processes Occur at Input?

It remains to explain the relationship of each of these models to the question, "Do generative processes occur at input?" Thus, it is necessary to derive a connection between the mode of processing at the input of a discourse and the dependence properties of the measures as expressed in Models I to IV. First, consider the case of a "generative processor." If the language comprehender behaves as a "generative processor," generative (e.g., inferential) processes will occur *during input*, resulting in a semantic structure in long term memory which contains both veridical and subject-generated elements. Thus, if we assume that the acquisition of new information occurs at input, then it is reasonable to expect that subject-generated (inferred and elaborative) semantic elements (as well as reproduced (veridical) elements) should exhibit stochastic growth properties, and that the observed growth in subject-generated elements should not be due solely to growth in the reproduced structure. Models III and IV represent this outcome. If, on the other hand, the person behaves as an "interpretive processor," generative processes will occur *only at output* either as retrieval processes or as operations on retrieved information. Under such circumstances, and with limited time at output, observed *growth* in subject-generated semantic elements ought to be attributable solely to growth in the reproduced structure which was acquired at input. Models I and II express this situation.

6.4 Results

Each of the four models was fit to the correlation matrix of Table 6.1 using Jöreskog's (1970b) program to obtain maximum likelihood estimates of all free parameters. The results for Models I-Iv are presented in Tables 6.3-6.6 respectively. In terms of goodness-of-fit of the alternative simplex models, the results are as follows:

Model	Assumptions	X^2	d.f.	P
I	(a) stochastic encoding process	79.53	58	.032
	(b) inference and elaborative production Spearman cases			
	(c) dependent processes			
II	(a) and (b) as above	90.20	67	.031
	(c) independent processes			
III	(a) as above	54.23	43	.117
	(b) inference and elaborative production stochastic			
	(c) as above			
IV	(a), (b), and (c) as above	43.68	39	.279
	(d) inference contributes to counts of elaborative relations			

Table 6.3

Veridical, Inferred, and Elaborative Relations

Parameter Estimates for Model I (a)

Trial	Measure	$\beta_{ti}^{(G)}$	$\beta_{ti}^{(I)}$	$\beta_{ti}^{(E)}$	α_t	ψ_t	θ_{ti}
1	Veridical Relations	1.000*			.941	.319	.000*
2	" "	1.000*			.749	.126	.000*
3	" "	1.000*			.815	.162	.000*
4	" "	1.000*			.938	.033	.000*
1	Inferred Relations	.244	.548				.807
2	" "	-.057	.568				.829
3	" "	-.040	.777				.637
4	" "	-.286	.686				.720
1	Elaborative Relations	.074		.628			.795
2	" "	-.160		.698			.645
3	" "	-.134		.554			.794
4	" "	-.280		.443			.804

*denotes parameter values specified by the model

$X^2 = 79.5344$; d.f. = 58, p = .032

Intercorrelations of Derived Measures (b)

Derived Measure

Derived Measure	G_1	G_2	G_3	G_4	I	E
Encoding, trial 1 (G1)	1.					
Encoding, trial 2 (G2)	.663	1.				
Encoding, trial 3 (G3)	.540	.789	1.			
Encoding, trial 4 (G4)	.506	.740	.863	1.		
Inferential Production (I)	-.043	.182	.156	.183	1.	
Elaborative Production (E)	-.339	-.322	-.312	-.307	-.011	1.

Intercorrelations of Derived Measures with Measures Obtained one Week Later (c)

Measure	G_1	G_2	G_3	G_4	I	E
Veridical Relations	.451	.694	.820	.823	.136	-.250
Inferred Relations	-.058	.038	.040	-.021	.663	.146
Elaborative Relations	-.246	-.335	-.314	-.380	-.024	.517

Table 6.4

Veridical, Inferred, and Elaborative Relations

Parameter Estimates for Model II (a)

Trial	Measure	$\beta_{ti}^{(G)}$	$\beta_{ti}^{(I)}$	$\beta_{ti}^{(E)}$	α_t	ψ_t	θ_{ti}
1	Veridical Relations	1.-*			.942	.316	.0*
2	" "	1.-*			.748	.126	.0*
3	" "	1.-*			.816	.162	.0*
4	" "	1.-*			.938	.033	.0*
1	Inferred Relations	.264	.533				.816
2	" "	.006	.568				.822
3	" "	.049	.771				.630
4	" "	-.206	.669				.724
1	Elaborative Relations	-.074		.554			.824
2	" "	-.329		.600			.704
3	" "	-.259		.573			.762
4	" "	-.377		.467			.780

*denotes parameter values specified by the model

$X^2 = 90.1972$, d.f. = 67, $p = .031$

Intercorrelations of Derived Measures (b)

Simple Production (Encoding) Process

Trial	1	2	3	4
1	1.-			
2	.663	1.-		
3	.541	.790	1.-	
4	.507	.741	.863	1.-

Intercorrelations of Derived Measures with Measures Obtained one Week Later (c)

Measure	G_1	G_2	G_3	G_4	I	E
Veridical Relations	.451	.697	.821	.823	-.018	.009
Inferred Relations	.022	.018	.040	-.034	.670	.133
Elaborative Relations	-.204	-.318	-.304	-.366	.045	.450

Table 6.5

Veridical, Inferred, and Elaborative Relations

Parameter Estimates for Model III (a)

Trial	Measure	$\beta_{ti}^{(G)}$	$\beta_{ti}^{(I)}$	$\beta_{ti}^{(E)}$	α_t	ψ_t	θ_{ti}
1	Veridical Relations	1.-*			.943	.315	.0*
2	" "	1.-*			.746	.128	.0*
3	" "	1.-*			.815	.162	.0*
4	" "	1.-*			.938	.033	.0*
1	Inferred Relations	.240	.673		1.-*		.712
2	" "	-.018	.743		.767		.671
3	" "	.051	.925		.751		.377
4	" "	-.192	.674		.879		.721
1	Elaborative Relations	-.043		.592	1.-*		.801
2	" "	-.323		.803	.986		.461
3	" "	-.293		.686	.556		.664
4	" "	-.394		.606	.896		.678

*denotes parameter values specified by the model
$X^2 = 54.2299$, d.f. = 43, $p = .117$

Intercorrelations of Derived Measures (b)

Simple Production (Encoding) Process

Trial	1	2	3	4
1 (G_1)	1.-			
2 (G_2)	.663	1.-		
3 (G_3)	.541	.788	1.-	
4 (G_4)	.507	.739	.863	1.-

Inferential Production Process

Trial	1	2	3	4
1 (I_1)	1.-			
2 (I_2)	.767	1.-		
3 (I_3)	.576	.751	1.-	
4 (I_4)	.506	.660	.811	1.-

Table 6.5 (continued)

Elaborative Production Process

Trial	1	2	3	4
1 (E_1)	1.-			
2 (E_2)	.986	1.-		
3 (E_3)	.548	.556	1.-	
4 (E_4)	.491	.498	.896	1.-

Intercorrelations of Derived Measures with Measures Obtained one Week Later (c)

Measure	G_1	G_2	G_3	G_4	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
Veridical Relations	.453	.683	.821	.821	.073	-.048	-.001	-.071	.017	.049	-.034	-.069
Inferred Relations	.035	.002	.039	-.038	.640	.422	.536	.696	.157	.086	.001	.065
Elaborative Relations	-.217	-.307	-.320	-.380	.234	.003	.004	.039	.348	.197	.521	.355

Table 6.6

Veridical, Inferred, and Elaborative Relations

Parameter Estimates for Model IV (a)

Trial	Measure	$\beta_{ti}^{(G)}$	$\beta_{ti}^{(I)}$	$\beta_{ti}^{(E)}$	α_t	ψ_t	θ_{ti}
1	Veridical Relations	1.000*			.942	.315	.0*
2	" "	1.000*			.747	.127	.0*
3	" "	1.000*			.816	.162	.0*
4	" "	1.000*			.938	.032	.0*
1	Inferred Relations	.242	.571		1.000*		.795
2	" "	-.009	.714		.896		.700
3	" "	.056	.913		.792		.402
4	" "	-.191	.985		.603		.000
1	Elaborative Relations	-.028	.211	.679	1.000*		.697
2	" "	-.306	-.048	.762	.923		.525
3	" "	-.282	-.113	.677	.586		.665
4	" "	-.383	-.197	.636	.899		.638

*denotes parameter values specified by the model
$X^2 = 43.6835$, d.f. = 39, p = .279

Intercorrelations of Derived Measures (b)

Simple Production (Encoding) Process

Trial	1	2	3	4
1	1.			
2	.663	1.		
3	.541	.789	1.	
4	.507	.740	.863	1.

Inferential Production Process

Trial	1	2	3	4
1	1.			
2	.896	1.		
3	.709	.792	1.	
4	.427	.477	.603	1.

Elaborative Production Process

Trial	1	2	3	4
1	1.			
2	.923	1.		
3	.540	.586	1.	
4	.486	.527	.899	1.

Table 6.6 (continued)

Intercorrelations of Derived Measures with Measures Obtained One Week Later (c)

Measure	G_1	G_2	G_3	G_4	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
Veridical Rel.	.453	.684	.822	.821	.087	-.052	.004	-.039	-.013	.047	-.037	-.067
Inferred Rel.	.034	.001	.036	-.041	.775	.443	.549	.473	.033	.090	.017	.068
Elab. Rel.	-.213	-.307	-.318	-.379	.278	-.009	-.016	.006	.243	.206	.525	.347

Residuals: S - Σ (d)

Measure	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Veridical															
1. trial 1	-.001														
2. trial 2	-.001	.001													
3. trial 3	-.009	.000	-.001												
4. trial 4	.020	.001	.001	.003											
5. trial 5	.003	.011	-.001	.002	.000										
Inferred															
6. trial 1	-.019	.136	.136	.117	.105	-.017									
7. trial 2	.010	.056	.070	.057	.056	.015	.000								
8. trial 3	-.059	.076	.028	.053	.026	-.039	.015	.003							
9. trial 4	-.153	.018	-.016	.026	.010	.025	-.039	.009	-.008						
10. trial 5	-.098	.039	.005	.017	.000	-.000	-.012	-.020	.010	.000					
Elaborative															
11. trial 1	-.112	-.100	-.161	-.136	-.125	.045	-.086	.021	.126	.045	.008				
12. trial 2	-.185	-.078	-.127	-.126	-.099	.048	-.095	-.035	.084	.034	.038	.047			
13. trial 3	-.039	-.113	-.023	-.020	-.021	-.064	-.114	.008	.133	.030	.026	.073	.006		
14. trial 4	-.081	-.051	.043	-.037	.010	.035	-.042	.029	.057	.069	.055	.043	-.037	.003	
15. trial 5	-.042	-.028	.004	-.002	.000	-.052	-.068	-.026	.056	.000	.057	.085	.008	.030	.000

Comparing Models I and II, it appears reasonable to regard the processes of encoding, inference, and elaborative production as independent. Among the four models, Model IV clearly has the best fit. Thus it is reasonable to regard the three processes as independent stochastic growth processes. In the first three columns of Table 6.6 (a) are estimates of the regression weights for encoding ($\beta_{ti}^{(G)}$), inference ($\beta_{ti}^{(I)}$), and elaborative production ($\beta_{ti}^{(E)}$) for each response class for each trial. Observe that for counts of inferred relations the weights on simple encoding decrease while weights on inference increase with trials. Similarly, for counts of elaborative relations the regression weights on encoding become negative, those on inference decrease with repeated exposure to the text, and weights on elaborative production increase on trial two and then decrease on subsequent trials. The numbers in column four reflect the rate of growth of encoding, inference, and elaborative production. The correlations of Table 6.6 (b) reflect the simplex property for encoding, inference, and elaborative production. Table 6.6 (c) presents the estimated correlations of encoding, inference, and elaborative production with counts of veridical, inferred, and elaborative relations obtained one week later. Interestingly, counts of veridical relations correlate highest (.821) with encoding on the last trial, but frequency of inferred relations correlated highest (.775) with inference on the first trial. The results would appear to strongly support the "generative semantic" view of comprehension processes and the assumption of process independence.

6.5 Effects of Contextual Conditions

In the results just described, stochastic models associated with alternative process models were compared with regard to their differential fit to the observed data. In order to provide a stronger test of the ability of the comparative model fitting technique employed here to reflect the processes operating in comprehension tasks, the models were fit separately to data obtained under each of the two experimental conditions: (A) the "natural" condition in which subjects were presented with a recorded discourse and then asked to write their reconstruction of the information which they had acquired from the discourse, and (B) the "problem solving" condition in which subjects were also required to generate for subsequent use as many different solutions as they could to a problem based on the content of the essay. Recall that the solution process required the subject to generate inferences which were constrained, i.e., the inferences had to be solution-related. Detailed consideration of the probable effects of condition B leads to the expectation that: (1) generative processes including inference should occur substantially at input, (2) subject-generated (e.g., inferred) elements should be relatively more independent of reproduced (veridical) elements than under condition A since they should be structurally more distinct, and (3) the production of subject-generated elements should be essentially non-cumulative. Thus, in terms of models fit to the data, the expectation was that Model II should fit the data obtained under condition B while (if the generative semantic model is valid) Model IV should fit the data obtained under condition A. Note that unlike condition A, for condition B, Model II should fit even though generative processes occur at input.

Results concerning mean frequencies of veridical, inferred, and elaborative relations indicate that condition B produced significantly more inferred relations after the first trial, that frequencies of inferred relations increased very little over trials for either condition, and that nearly identical frequencies of veridical relations occurred for the two conditions. In general, the effects of the conditions on mean frequencies were small. The within group intercorrelations for the fifteen measures for conditions A and B are reported in Tables 6.7 and 6.8 respectively. Examination of the appropriate submatrices in Table 6.8 suggests that under condition B, inferred and elaborative responses do not have simplex properties. Now consider the "control" condition (A). Models II and IV were fit to the matrix of Table 6.7 with the following results (see also Table 6.9):

	Chi-square	d.f.	p
Model II	98.25	67	.008
Model IV	52.39	39	.091

Thus it appears as if Model IV should be selected although the assumption of independent processes is probably not valid. In other words, it appears as if under the "natural" conditions, subjects behave as generative semantic processors. The results for the problem-solving condition (B) are summarized in Table 10: Model II fits extremely well (chi-square 63.61, $p = .595$, d.f. = 67). Thus while the effects of the experimental conditions on mean frequencies were modest, the analysis of correlated growth results in a dramatic difference entirely consistent with theoretical expectations.

Certain problems occurred in fitting Model IV to the correlation matrix of Table 6.7 which should be noted. While some parameters appear to have been estimated accurately, others appear to be rather far from their final values. This fact is apparent from observing the correlations of the extension variables with latent variables I_1 and I_2 (Table 6.10 (c)): These latter variables have a correlation of one and hence the correlations of the extension variables with I_1 and I_2 should be equal. This result may be due to some sort of "ridge effect" in the likelihood function.

Table 6.7

Multi-Occasion Intercorrelations of Response Class
Frequencies Based on Veridical, Inferred, and Elaborative
Relations for Group A

Variate Response Class	Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Veridical Relations	1															
2. " "	2	.642														
3. " "	3	.433	.799													
4. " "	4	.469	.717	.867												
5. " "	R	.441	.712	.833	.761											
6. Inferred Relations	1	.062	.306	.241	.143	.257										
7. " "	2	-.214	.042	.027	.017	.046	.450									
8. " "	3	-.125	.156	.066	.066	.068	.257	.447								
9. " "	4	-.362	-.114	-.113	-.097	-.091	.083	.278	.630							
10. " "	R	-.265	.046	.077	-.047	.010	.342	.435	.584	.600						
11. Elaborative Relations	1	.026	-.025	-.226	-.166	-.101	.134	-.016	.070	.177	.216					
12. " "	2	-.303	-.312	-.310	-.242	-.193	.018	-.187	-.127	.152	.020	.570				
13. " "	3	-.219	-.454	-.494	-.346	-.399	-.213	-.298	-.236	.025	-.193	.236	.563			
14. " "	4	-.129	-.247	-.328	-.429	-.344	.069	-.062	-.231	-.265	.016	.190	.349	.412		
15. " "	R	-.267	-.339	-.323	-.257	-.308	.050	-.107	-.189	.010	-.115	.278	.342	.451	.256	

N = 47

Table 6.8

Multi-Occasion Intercorrelations of Response Class
Frequencies Based on Veridical, Inferred, and Elaborative
Relations for Group B

Variate

Response Class	Trial	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Veridical Relations	1															
2. " "	2	.706														
3. " "	3	.582	.792													
4. " "	4	.538	.760	.872												
5. " "	R	.469	.692	.820	.884											
6. Inferred Relations	1	.320	.272	.259	.292	.254										
7. " "	2	.170	.027	.085	.080	-.031	.324									
8. " "	3	.044	.063	.125	.168	.097	.420	.622								
9. " "	4	-.149	-.123	-.216	-.206	-.264	.382	.274	.397							
10. " "	R	.053	-.002	-.008	-.019	-.021	.525	.200	.392	.380						
11. Elaborative Relations	1	-.280	-.257	-.184	-.178	-.188	.183	.116	.232	.240	.254					
12. " "	2	-.480	-.458	-.372	-.405	-.322	-.063	-.046	-.001	.071	.140	.443				
13. " "	3	-.174	-.199	-.144	-.193	-.168	-.080	-.021	.055	.213	.137	.313	.306			
14. " "	4	-.351	-.410	-.265	-.420	-.335	-.154	-.161	.035	.136	.045	.305	.383	.510		
15. " "	R	-.271	-.371	-.332	-.502	-.445	.067	-.023	.080	.249	.218	.318	.328	.477	.500	

Table 6.9

Veridical, Inferred, and Elaborative Relations: Model IV
Fit to Group A Correlation Matrix

Parameter Estimates for Model (a)

Trial	Measure	$\beta_{ti}^{(G)}$	$\beta_{ti}^{(I)}$	$\beta_{ti}^{(E)}$	α_t	ψ_t	θ_{ti}
1	Veridical Relations	1.*			.911	.376	.0*
2	" "	1.*			.777	.000	.0*
3	" "	1.*			.797	.110	.0*
4	" "	1.*			.899	.041	.0*
1	Inferred Relations	.125	.577		1.*		.838
2	" "	-.089	.902		1.000		.465
3	" "	.030	.978		.538		.188
4	" "	-.134	1.003		.654		.000
1	Elaborative Relations	.143	.115	.806	1.*		.619
2	" "	-.216	-.105	.942	.794		.000
3	" "	-.461	-.182	.583	.666		.610
4	" "	-.418	-.367	.555	.902		.655

*denotes parameter values specified by the model
$X^2 = 52.3923$, d.f. = 40, p = .091

Intercorrelations of Derived Measures (b)

Simple Production (Encoding) Process

Trial	1	2	3	4
1 (G_1)	1.			
2 (G_2)	.645	1.		
3 (G_3)	.514	.797	1.	
4 (G_4)	.462	.716	.865	1.

Inferential Production Process

Trial	1	2	3	4
1 (I_1)	1.			
2 (I_2)	1.000	1.		
3 (I_3)	.538	.538	1.	
4 (I_4)	.352	.352	.654	1.

Table 6.9 (continued)

Trial	1	2	3	4
1 (E_1)	1.			
2 (E_2)	.794			
3 (E_3)	.529	.666	1.	
4 (E_4)	.477	.601	.902	1.

Intercorrelations of Derived Measures with Measures Obtained One Week Later (c)

Measure	G_1	G_2	G_3	G_4	I_1	I_2	I_3	I_4	E_1	E_2	E_3	E_4
Veridical Relations	.520	.704	.834	.746	.099	.071	.037	.027	.052	.084	.016	-.104
Inferred Relations	-.069	-.051	.054	-.053	.640	.493	.584	.582	.253	.064	.054	.304
Elaborative Relations	-.308	-.377	-.348	-.292	.361	.024	-.080	-.013	.285	.140	.419	.261

Table 6.10

Veridical, Inferred, and Elaborative Relations: Model II Fit to Group B Correlation Matrix

Parameter Estimates for Model II (a)

Trial	Measure	$\beta_{ti}^{(G)}$	$\beta_{ti}^{(I)}$	$\beta_{ti}^{(E)}$	α_t	ψ_t	θ_{ti}
1	Veridical Relations	1.*			.982	.186	.0*
2	" "	1.*			.733	.125	.0*
3	" "	1.*			.814	.179	.0*
4	" "	1.*			.958	.027	.0*
1	Inferred Relations	.304	.625				.708
2	" "	.013	.575				.815
3	" "	.092	.738				.657
4	" "	-.256	.620				.755
1	Elaborative Relations	-.222		.412			.872
2	" "	-.415		.334			.827
3	" "	-.135		.765			.642
4	" "	-.365		.574			.711

*denotes parameter values specified by the model

X^2 = 63.6132, d.f. = 67, p = .595

Intercorrelations of Derived Measures (b)

	Derived Measure			
Derived Measure	G_1	G_2	G_3	G_4
Encoding, tr. 1 (G_1)	1.			
Encoding, tr. 2 (G_2)	.707	1.		
Encoding, tr. 3 (G_3)	.576	.790	1.	
Encoding, tr. 4 (G_4)	.552	.757	.869	1.

Intercorrelations of Derived Measures with Measures Obtained one Week Later (c)

	G_1	G_2	G_3	G_4	I	E
Veridical Relations	.478	.689	.816	.883	-.076	.023
Inferred Relations	.082	.038	.012	.003	.570	.088
Elaborative Relations	-.202	-.286	-.295	-.438	.110	.519

CHAPTER 7

SOURCES OF INDIVIDUAL DIFFERENCES IN COMPREHENSION AND SEMANTIC MEMORY

7.1 Introduction

The questions which have been investigated thus far have been concerned with identifying characteristics of information processing activities in the acquisition of semantic knowledge from discourse under "normal" contextual conditions (including limits on processing capacity and adjustments to limits on processing through processes of simplication and generative inference), and with investigating effects of repeated exposures and contextual conditions on these processes by studying their effects on semantic information which is acquired from a text. A question of particular interest has been the extent to which generative processing activities occur and the role of these processes in discourse comprehension and semantic memory. The results obtained were found to be consistent with a generative processing model and indicate not only that generative processes occur during the time in which a discourse is input, but that the nature of these processing activities (and hence the nature of the semantic information acquired from a discourse) may be influenced by contextual conditions which induce further processing of the semantic information once it has been acquired. If, in fact, the conception of discourse comprehension and semantic memory as a hierarchiacally organized multi-level sequence of processing operations with generative operations occurring at the top (cf. Figure 4.2) is correct; and if the extent of generative processing is affected by properties of a discourse and contextual conditions; it is also reasonable to expect that individuals will differ in the extent to which they process texts interpretively or generatively. Thus as information processing activities in normal comprehension and semantic memory are understood, possible sources of individual differences in these processing activities may be identified. Once potential sources of individual differences have been identified, it may be possible to obtain measurements of differences in these processing activities. One possible set of measures are those used in the present study: relative frequencies of particular classes of semantic information in individuals' recall protocols. Thus relative frequencies of subject-generated semantic relations may provide reliable measures of the extent to which an individual processes semantic information generatively. Such measurements may eventually be useful in practical situations, e.g. in diagnosing sources of difficulties in oral and written comprehension. For example, if a child should consistently show an unusually low frequency of inferred semantic elements in protocols obtained in a "story retelling" task, this would indicate a failure to process discourse inputs generatively and thus identify the source of his difficulty in comprehending school materials.

In any task involving a sequence of processing operations, (differences between individuals can occur both qualitative and quantitative:) Qualitative differences can occur if individuals differ in the particular sequence of processing operations which they employ. Thus, in terms of the model summarized in Figures 4.1-4.3, individuals may differ in the particular elements processed at each level: in terms of both types and size of elements segmented or selected; and they may differ in the sequence of processing operations which they employ: in the extent of processing at each level and in constituent processes at each level. Qualitative differences would also appear to be likely as a result of differences in the availability of previously acquired semantic information stored in long term memory. Quantitative differences may occur if individuals differ with respect to the relative efficiency of any constituent processing operations, or in the efficiency with which constituent operations are combined. Such quantitative differences would be expected to produce differences in measures of comprehension, even if no qualitative differences occurred among individuals, i.e., even if each individual processed a discourse in exactly the same manner. This distinction between qualitative and quantitative sources of individual differences might be described as a distinction between individual differences related to *mode* of processing and to the *efficiency* of processing. For example, surface or syntactic characteristics may be processed more extensively by some people when processing discourse, while others may pay more attention to semantic distinctions. Once a processing strategy is chosen, the efficiency variable refers to differences in the knowledge or skill needed to use that strategy in a competent manner. For a person who chose to process the surface and syntactic information, a good knowledge of grammar and interpretive rules would be necessary to process efficiently, whereas for a generative (semantic) processor, an ability to make previously stored semantic information available and to efficiently generate and evaluate plausible semantic interpretations would be needed for efficient comprehension. In the present chapter, both quantitative and qualitative sources of individual differences will be examined.

While most studies of individual differences in language comprehension have tended to focus on outcomes, measuring comprehension on various tasks designed to assess level of proficiency on different comprehension skills (such as recalling word meanings, drawing inferences about the meaning of words from context; finding answers to questions where the answer was stated in the text; drawing inferences; following the structure of the passage; recognizing the writer's purpose, etc., cf. Davis, 1968), the focus in the present study is on specific outcomes, qualitative and quantitative differences in the sequence of processing operations which generate these outcomes, and on effects of properties of a discourse and of contextual conditions on these differences. This chapter will consider first sources of individual differences related to the efficiency of various constituent processes in language comprehension and semantic memory. The method adopted will be to obtain measures of specific narrowly defined "abilities" to estimate a subject's probable level of efficiency with respect to various constituent operations in processing discourse and to study predictive relationships between these measures and measures obtained from the analysis of subjects' recall protocols. High correlations with a particular ability measure would be expected to result if:

(1) the constituent processes related to the ability occurred as a part of the sequence of processing activities for most or all of the subjects, and (2) the relative efficiency of these processes has an effect on the extent to which particular semantic information is acquired. Suppose, for example, that a non-verbal measure of inferential reasoning "ability" were available which measured the efficiency with which an individual is able to inferentially generate and evaluate semantic information. To the extent that inferential processes are a part of discourse processing in all subjects, and to the extent that efficient inferential processing results in the acquisition of semantic information, the ability measure should be capable of predicting semantic measures obtained from subjects' recall protocols. Furthermore, the magnitude of this correlation should be affected by the same contextual factors which were previously found to affect the extent of inferential operations in processing discourse. Thus, as in Chapter 5, we will be interested in both (1) the magnitudes of individual ability-response class correlations in "normal" comprehension (condition A), and (2) experimentally-induced differences in ability-response class correlations. The rationale underlying this approach involves interpreting a high correlation between a specific ability measure and response class as indicative of the particular process or processes involved in generating responses of that class (cf. Frederiksen, 1969). Since this rationale depends on the notion of shared processes, processes shared between the ability measure and the response class, it is important to establish that the two measures have in common only the process which is of interest. Thus, a correlation of a verbal reasoning measure and frequencies of inferred relations could reflect many common processes other than reasoning operations since the ability test is itself a measure of comprehension. It should now be clear how a carefully designed study of individual differences in processing efficiency can provide valuable information concerning normative processing events in comprehension and semantic memory.

The remaining sections of this chapter will focus on qualitative differences among individuals -- on possible differences in strategies used to select semantic information for further processing and long term storage; to retrieve information from memory (including selection of entry points to semantic structures in LTM, organizational processes, and directed search strategies); and to generate new semantic information from information which has been acquired from a discourse or retrieved from LTM. Questions to be asked concerning qualitative sources of individual differences include: (1) determining whether reliable differences among individuals occur under conditions of "normal" comprehension, (2) investigating effects of contextual conditions on strategy selection, and (3) attempting to identify combinations of strategy statements which define integrated processing strategies which include strategies for selection, organization, generative operations, and retrieval strategies. This latter question will be studied by analyzing matrices of intercorrelations of strategy measures obtained under each condition by attempting to find a simple linear factor model involving a small number of factors from which the correlation matrix can be reproduced. Since information processing strategies identified in this way are obtained from analyses of strategy-intercorrelations, any such strategy factors by definition represent qualitative sources of individual differences.

7.2 Cognitive Abilities and Processing Operations in Discourse Comprehension and Semantic Memory

The approach to the study of individual differences in comprehension and memory processes to be described in this section involves attempting to predict frequencies of classes of semantic elements on subjects' protocols from measurements of abilities related to specific processes which may be involved in generating these elements, and studying the effects of contextual conditions on these predictive relationships. For purposes of selecting and classifying ability measures, constituent processes in comprehension and memory were classified into interpretive processes, unconstrained generative processes (associated with elaboration), generative inference, output expressional processes, storage and retrieval processes, processes associated with buffer storage, and processes associated with the identification and maintenance of semantic elements. Ability measurements related to each of these classes were obtained and used to predict response class frequencies separately for each experimental context. Fifteen tests were originally selected (see Chapter 5), but only twelve tests were proved to have sufficiently high sample reliabilities to be included in subsequent analyses (Table 7.1). The tests retained have been found to measure the following cognitive abilities (cf. French, Ekstrom, & Price, 1963):

Closure:	1.	Cf	(Flexibility of closure): Maintenance of a visual pattern in a distracting visual field (Hidden Patterns Test)
	2.	Cs	(Speed of closure): Speed of identification of a visual pattern in which a distracting pattern interrupts contours (Gestalt Completion Test)
Fluency:	1.	Fe	(Expressional fluency): Facility in producing connected discourse that will fit restrictions imposed in terms of given ideas (Word Arrangement Test)
	2.	Fi	(Ideational Fluency): Facility in producing quantities of verbally expressed ideas (Themes, score is number of words written; Topics, score is number of phrases or sentences written).
	3.	Fa	(Associational Fluency): Constrained associative production of a single word (Controlled Associations)
Reasoning:	1.	Rs	(Syllogistic Reasoning): Application of rules of deductive logic to evaluate propositions. (Inference Test)
	2.	I	(Induction): Generation and evaluation of rules from examples to eliminate one set of several sets of letters (Letter Sets)

Memory: 1. Ms (Memory Span): Length of a string of letters which can be maintained briefly in an auditory rehearsal buffer (Auditory Letter Span)
2. Ma (Associative Memory): Paired-associate learning (First and Last Names Test)

Vocabulary: V Size of comprehension vocabulary

The matrix of intercorrelations of these twelve ability tests is presented in Table 7.1. The relationship of each of these abilities to the classes of constituent processes is as follows: interpretive processes: vocabulary (interpretation of lexical elements); unconstrained generative processes: ideational fluency; inferential processes: reasoning; output expressional processes: expressional fluency; buffer storage: memory span; processes associated with the identification and maintenance of a structural element: the closure factors. Since it appeared as if, of the fluency tests, "Themes" and "Topics" might measure expressional fluency as well as ideational fluency (i.e. since scores reflect amount written); and since it was desired to obtain a single measure of reasoning which did not involve verbal comprehension, the matrix of intercorrelations of these tests was analyzed by fitting alternative linear factor models to the matrix until that model was found which best fit the correlation matrix. The model is summarized in Table 7.2 and differs from the familiar linear factor model only with respect to the treatment of a subset of the tests as extension variables (variables which are not included in the analysis except to estimate their correlations with the factors which were fit to the subset of tests which were analyzed). Maximum likelihood estimates of all free parameters were obtained using Jöreskog's (1970) estimation program and the fit of the model of Table 7.3 was found to be excellent ($\chi^2(35) = 20.2498$, $p = .978$). Note that, just as in Chapter 6, small value of chi-square and large p values indicate that the fit of the model to the data is good. Parameter estimates obtained for the resulting best-fitting model are presented in Table 7.3. Four factors were found: (1) an ideational fluency factor measured by Topics, Word Arrangement, and Controlled Associations, (2) an expressional fluency factor measured by Topics, Themes, and Word Arrangement, (3) the expected reasoning factor, and (4) a closure factor measured by Four-Letter Words and Letter Sets. Both of these latter two tests involve recognizing a letter pattern embedded in a larger sequence. The intercorrelations of these factors are given in Table 7.3b. Reasoning is uncorrelated with expressional fluency and also has very little correlation with verbal closure. Correlations of the extension variables with the four factors are found in Table 7.3c. In general, the measures appear to be rather independent of each other.

Results obtained concerning the predictive relationships of the four ability factors and five extension variables with frequencies of

Table 7.1

Pooled Within-Group Estimates of Intercorrelations of Scores on Twelve Cognitive Ability Tests and Estimated Reliabilities

Test	Intercorrelations												Reliability Estimate*
	1	2	3	4	5	6	7	8	9	10	11	12	
1. Gestalt Completion (Cs-1)	1.-												.789
2. Hidden Patterns (Cf-2)	.259	1. -											.899
3. Topics (Fi-1)	.112	.357	1. -										.814
4. Themes (Fi-2)	.059	.076	.425	1. -									.860
5. Word Arrangement (Fe-3)	.080	.112	.457	.511	1. -								.775
6. Controlled Associations (Fa-1)	-.010	.170	.403	.154	.335	1. -							.747
7. Inference (Rs-3)	.237	.243	.195	.053	.090	.227	1. -						.679
8. Letter Sets (I-1)	.139	.160	.194	.173	.203	.166	.429	1. -					.765
9. Four Letter Words (Cs-3)	-.039	.196	.246	.300	.237	.120	.136	.351	1. -				-
10. Auditory Letter Span (Ms-3)	.180	.018	.194	.207	.148	.184	.166	.201	.020	1. -			.710
11. First and Last Names (Ma-3)	.038	.120	.195	.106	.070	.240	.225	.222	.264	.108	1. -		.881
12. Advanced Vocabulary (V-4)	.215	.155	.137	.080	.226	.235	.360	.257	.250	.142	.168	1. -	.794

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* Split half reliabilities corrected for double length by Spearman-Brown formula.

Table 7.2

Summary of Model Fit to Matrix of Intercorrelations of Ability Tests

Assumptions: Linear Factor Model

(1) $\underline{y} = \Lambda \underline{x} + \underline{z}$ where $\underline{y}$ = random vector of p test scores

Λ = matrix of regression weights

$\underline{x}$ = random vector of factor scores

(2) $\mathrm{var}(\underline{y}) = \Sigma = \Lambda \Phi \Lambda' + \Psi^2$

(3) $\mathrm{var}(\underline{x}) = \Phi$ (a correlation matrix)

(4) $\mathrm{var}(\underline{z}) = \Psi^2$ (a diagonal matrix)

(5) $E(\underline{x}) = E(\underline{z}) = \underline{o}$

Assumptions: Linear Factor Model with Extension Variables

let $\underline{y} = \left[\begin{array}{c} \underline{y}_1 \\ \hdashline \underline{y}_2 \end{array}\right]$ where $\underline{y}_1$ = a random vector of scores on p_1 tests to be factored

$\underline{y}_2$ = a random vector of p_2 extension variables

(6)

$$\Sigma = \left[\begin{array}{c:c} \Sigma_{11} & \Sigma_{12} \\ \hdashline \Sigma_{12} & \Sigma_{22} \end{array}\right] = \left[\begin{array}{c:c} \Lambda_1 & 0 \\ \hdashline 0 & I \end{array}\right] \left[\begin{array}{c:c} \Phi_{11} & \Phi_{12} \\ \hdashline \Phi_{12}' & \Sigma_{22} \end{array}\right] \left[\begin{array}{c:c} \Lambda_1' & 0 \\ \hdashline 0 & I \end{array}\right] + \left[\begin{array}{c:c} \Psi_1^2 & 0 \\ \hdashline 0 & 0 \end{array}\right]$$

then $\Phi_{12} = \mathrm{cov}(\underline{x}, \underline{y}_2)$, the correlations of the extension variables with the factors

(7) $\Sigma_{11} = \Lambda_1 \Phi_{11} \Lambda_1' + \Psi_1^2$

(8) $\Sigma_{12} = \Lambda_1 \Phi_{12} \Rightarrow \Phi_{12} = (\Lambda_1' \Lambda_1)^{-1} \Lambda_1 \Sigma_{12}$

Table 7.3

Maximum Likelihood Estimates of Parameter Values for Model
Fit to Matrix of Intercorrelations of Ability Tests

Factor Pattern Matrix
(Matrix of Regression Weights of Tests on Factors, Λ_1) (a)

Test	Factor Loadings 1	2	3	4	Standard Deviation of Specific Part Ψ_1
3. Topics	.536	.356	.0*	.0*	.689
4. Themes	.0*	.831	.0*	.0*	.556
5. Word Arrangement	.294	.526	.0*	.0*	.739
6. Controlled Associations	.658	.0*	.0*	.0*	.753
7. Inference	.0*	.0*	.818	.0*	.575
8. Letter Sets	.0*	.0*	.473	.290	.802
9. Four Letter Words	.0*	.0*	.0*	.939	.345

χ^2 (35) = 20.2498, p = .978

* denotes parameter values fixed by the model

Intercorrelations of Factors
(Φ_{11} Matrix) (b)

Factor	1	2	3	4
1. Ideational Fluency (Fi)	1. - *			
2. Expressional Fluency (Fe)	.294	1. - *		
3. Reasoning (Rs)	.398	.084	1. - *	
4. Verbal Closure (Cv)	.207	.388	.178	1. - *

Correlation of Extension Variables with Factors (c)

Test	Factor 1	2	3	4
1. Speed of Closure (Cs)	.062	.092	.294	-.041
2. Flexibility of Closure (Cf)	.386	.105	.285	.206
10. Memory Span (Ms)	.234	.227	.233	.026
11. Associative Memory (Ma)	.309	.096	.279	.281
12. Vocabulary (V)	.311	.107	.432	.265

veridical, overgeneralized, pseudodiscriminated, inferred, and elaborative semantic relations will now be presented. The results will be presented pertaining to each of the six classes of processing operations or processor characteristics in comprehension and semantic memory: (1) generative inference, (2) unconstrained generative processes, (3) expressional processes, (4) processes associated with the identification and maintenance of structural information, (5) processes involved in the memory system (including buffer capacity), and (6) relative size of the comprehension vocabulary (i.e. number of lexical elements for which accurate semantic information can be retrieved from memory). In examining the results which follow, it is important to realize that of the set of semantic relations considered, veridical and overgeneralized semantic relations do not reflect subject-generated semantic elements; pseudodiscriminated, inferred, and elaborative semantic relations all involve subject-generated elements in some way. The latter three response classes differ with respect to the manner and extent to which generated semantic information is constrained, e.g. by the discourse or by particular derivational rules such as rules of inference. The intercorrelations of the above response measures obtained under condition A were reported in Table 3.2; intercorrelations of frequencies of classes of semantic relations obtained from subjects' protocols under conditions B and C are reported in Tables 7.4 and 7.5 respectively. Correlations of these classes of semantic responses with the nine "efficiency" variables (four factors and five extension tests) for each of the three experimental conditions are reported in Tables 7.6, 7.7, and 7.8.

Consider first the results concerning inferential processes (factor Rs). The two tests which were selected as measures of reasoning ability: Inference (the test items involve selecting correct conclusions which can be drawn from given statements) and Letter Sets (the task involves finding a rule which related sets of four letters and eliminating a fifth set of letters which does not fit the rule) both involve a requirement that the subject be able to generate and evaluate inferences. Recall that the procedure used was to estimate the factor common to the two tests and use this inferential reasoning factor to predict response measures. This factor by definition will be independent of verbal factors since only one of the tests involves verbal content. Thus correlations of response measures with this estimated reasoning factor are not due to common verbal content. Correlations of reasoning ability with frequencies of veridical, inferred, and elaborative relations are found in column 3, Table 7.6, 7.7, and 7.8. A number of results are apparent: (1) frequencies of veridical relations are predictable from reasoning for all contexts; (2) with only one exposure to the passage, reasoning correlates highest with veridical relations for condition B, but the correlation for condition A increases with repeated exposures to the text and surpasses that of condition B; (3) inferred relations are predictable from reasoning only under condition B; and (4) reasoning is negatively

Table 7.4 (a)

Multi-Occasion Intercorrelations of Response Class Frequencies
Based on Veridical, Overgeneralized, Pseudodiscriminated,
Inferred, and Elaborative Semantic Relations, Condition B

		Veridical					Overgeneralized					Pseudodiscriminated				
Response Class	Trial	1	2	3	4	R	1	2	3	4	R	1	2	3	4	R
Veridical	1	--														
Semantic	2	.706	--													
Relations	3	.582	.792	--												
	4	.538	.760	.872	--											
	R	.469	.692	.820	.884											
Overgeneralized	1	.252	.246	.230	.247	.043	--									
Semantic	2	.300	.416	.446	.483	.385	.337	--								
Relations	3	.077	.278	.318	.459	.350	.285	.514	--							
	4	.123	.173	.345	.322	.182	.398	.282	.485	--						
	R	.229	.174	.239	.311	.219	.342	.362	.588	.465						
Pseudodiscrim-	1	.146	.012	-.009	-.130	-.146	.091	-.113	-.030	-.108	.151					
inated Semantic	2	.213	-.066	.089	.106	.076	.026	-.330	-.052	.210	.161	.082	--			
Relations	3	.053	-.035	-.073	.024	-.052	.136	-.164	-.031	.159	.039	.148	.443	--		
	4	.052	.121	.192	.199	.254	-.033	-.132	-.089	-.037	-.028	.237	.296	.311	--	
	R	.067	.176	.094	.031	.020	.179	.035	.132	-.090	-.043	.319	.052	.322	.231	--

N = 49

Table 7.4 (b)

Response Class	Trial	Veridical					Overgeneralized					Pseudodiscriminated				
		1	2	3	4	R	1	2	3	4	R	1	2	3	4	R
Inferred Semantic Relations	1	.320	.272	.259	.292	.254	.039	.140	-.024	.137	.124	-.017	.301	-.042	.112	-.203
	2	.170	.027	.085	.080	-.031	.093	-.138	-.101	.014	.143	.108	.231	-.061	.041	.022
	3	.044	.063	.125	.168	.097	.049	-.111	-.089	-.034	-.053	-.047	.171	-.099	.195	-.052
	4	-.149	-.123	-.216	-.206	-.264	-.287	-.121	-.168	-.076	-.234	-.213	-.136	-.232	-.147	-.175
	R	.053	-.002	-.008	-.019	-.021	.190	.074	-.270	.135	-.145	-.085	.091	.034	.138	-.111
Elaborative Semantic Relations	1	-.280	-.257	-.184	-.178	-.188	-.009	-.158	-.016	-.043	-.117	-.283	.227	-.108	-.159	-.007
	2	-.480	-.458	-.372	-.405	-.322	-.097	-.184	-.036	-.178	-.125	-.119	.032	-.080	-.294	.040
	3	-.174	-.199	-.144	-.193	-.168	.116	-.037	-.175	.109	-.049	-.335	-.107	-.209	-.257	-.165
	4	-.351	-.410	-.265	-.420	-.335	-.049	-.132	-.218	-.077	-.189	-.122	-.149	-.104	-.061	-.116
	R	-.271	-.371	-.332	-.502	-.445	.152	-.088	-.146	.037	-.165	-.046	-.145	-.209	-.249	-.185

Table 7.4 (c)

Response Class	Trial	Inferred					Elaborative				
		1	2	3	4	R	1	2	3	4	R
Inferred Semantic Relations	1	-									
	2	.324	-								
	3	.420	.622	-							
	4	.382	.274	.397	-						
	R	.525	.200	.392	.380	-					
Elaborative Semantic Relations	1	.183	.116	.232	.240	.254	-				
	2	-.063	-.046	-.001	.071	.140	.443	-			
	3	-.080	-.021	.055	.213	.137	.313	.306	-		
	4	-.154	-.161	.035	.136	.045	.305	.383	.510	-	
	R	.067	-.023	.080	.249	.218	.318	.328	.477	.500	-

Table 7.5

Intercorrelations of Response Class Frequencees Based on
Veridical, Overgeneralized, Pseudodiscriminated, Inferred, and
Elaborative Semantive Relations, Trial 4 and Reminiscence,
Condition C

Response Class	Trial	Veridical		Overgeneralized		Pseudodiscriminated		Inferred		Elaborative	
		4	R	4	R	4	R	4	R	4	R
Veridical	4	-									
	R	.670	-								
Overgeneralized	4	-.211	.011	-							
	R	.174	.256	.393	-						
Pseudodiscriminated	4	.155	.406	.069 -	-.011	-					
	R	.175	.192	.268	.418	.135	-				
Inferred	4	-.022	.052	.005	.082	-.285	-.117	-			
	R	.249	.252	.076	.062	-.067	-.141	.345	-		
Elaborative	4	-.319	-.222	.079	-.061	.031	-.118	-.053	.017	-	
	R	.004	-.234	.006	.054	-.131	.084	-.127	-.025	.621	-

N = 45

Table 7.6

Least-Squares Estimates of Correlations of Estimated Ability Factors and Correlations of Extension Variables with Response Class Frequencies Based on Semantic Relations, Condition A

		Factors				Extension Variables				
Response Class	Trial	Fi	Fe	Rs	Cv	Cs	Cf	Ms	Ma	V
Veridical	1	.259	-.035	.108	.136	.003	.160	.036	.190	.123
Semantic	2	.256	.186	.566**	.078	.112	.198	.251	.277	.493**
Relations	3	.387**	.108	.578**	-.057	-.010	.115	.231	.286	.369*
	4	.491**	.235	.499**	.044	-.138	.137	.242	.324*	.342*
	R	.265	.086	.453**	.078	.012	.151	.131	.408**	.380**
Over-	1	.450**	.143	.234	.110	-.027	.169	.128	.318*	.157
generalized	2	.017	.144	-.015	-.132	-.240	-.297*	.207	.136	-.048
Semantic	3	.183	.171	.154	-.163	-.337*	-.193	.147	.083	-.099
Relations	4	.050	.491**	.061	-.048	-.206	-.033	.257	-.087	-.074
	R	.192	.311*	.452**	-.252	-.065	.084	.470**	.092	.201
Pseudo-	1	.110	-.065	.027	.182	.196	-.003	-.034	.076	.172
discriminated	2	.199	.233	.363*	.173	-.001	.114	-.185	.139	.218
Semantic	3	.316*	.012	.100	.015	-.109	.033	-.206	.327*	.141
Relations	4	-.337*	.322*	-.326*	.101	.080	-.152	-.217	-.011	-.066
	R	-.143	.273	.073	-.048	.003	-.230	-.008	.041	.055
Inferred	1	.350*	-.087	.214	.364*	.275	.318*	.278	-.018	.378*
Semantic	2	.196	-.184	.138	.200	.140	.235	.258	.098	.305*
Relations	3	.084	.237	.216	.143	.084	.190	.199	.224	.403**
	4	.129	.378*	.069	-.021	.089	.222	.192	-.045	.231
	R	.064	.126	.058	.223	.309*	.234	.079	-.050	.258
Elaborative	1	.128	.188	-.276	.060	.020	.090	-.005	.049	-.128
Semantic	2	.029	.024	-.214	.067	-.092	.044	-.084	.030	-.224
Relations	3	-.049	.006	-.408**	.133	-.102	-.166	-.051	-.056	-.321*
	4	.045	-.270	-.248	.325*	.173	.109	-.173	-.038	-.064
	R	-.002	.040	-.149	-.004	-.136	-.005	-.003	.101	-.068

N = 47

* = $p < .05$
** = $p < .01$

Table 7.7

Least-squares Estimates of Correlations of Estimated Ability Factors and Correlations of Extension Variables with Response Class Frequencies Based on Semantic Relations, Condition B

		Factors				Extension Variables				
Response Class	Trial	Fi	Fe	Rs	Cv	Cs	Cf	Ms	Ma	V
Veridical	1	-.009	.154	.378**	.004	.312*	.355*	-.089	-.058	.099
Semantic	2	.129	.249	.384**	.157	.248	.354*	-.019	.093	.239
Relations	3	.355*	.480**	.384**	.433**	.216	.471**	.070	.194	.298*
	4	.320*	.504**	.436**	.390**	.333*	.433**	.144	.173	.270
	R	.328*	.305*	.345*	.364*	.313	.401**	.189	.087	.298*
Over-	1	.415**	.328*	.129	.233	.094	.273	.079	.318*	.019
generalized	2	.282*	.136	.315*	.172	.041	.303*	.138	.168	.096
Semantic	3	.213	.366*	.075	.381**	.138	.326*	.140	.110	.086
Relations	4	.479**	.425**	.078	.404**	.068	.243	.036	.238	.192
	R	.338*	.289*	.078	.336*	.058	.378	-.148	.112	-.027
Pseudo-	1	.100	-.208	.274	.026	.045	.007	-.148	.004	-.182
discriminated	2	-.028	.264	.138	.205	.098	.189	-.000	.056	.093
Semantic	3	.088	-.019	.177	.068	-.064	-.041	.204	-.099	-.077
Relations	4	.385**	-.067	.367*	.176	.185	-.019	.219	.075	.087
	R	.398**	-.053	.287*	.259	-.228	.081	-.030	.220	-.009
Inferred	1	-.169	.156	.266	-.034	.109	.113	-.048	-.139	.248
Semantic	2	.135	.047	.432**	.014	.198	.199	-.152	.223	.132
Relations	3	.056	.359*	.590**	.046	.183	.121	.071	.202	.157
	4	-.124	-.046	.140	-.249	.100	-.188	.027	-.174	.136
	R	.166	.166	.267	-.170	.213	-.074	.177	-.126	.233
Elaborative	1	-.184	.043	-.104	-.001	-.249	-.088	.103	.055	.211
Semantic	2	.003	-.261	-.479**	-.142	-.380**	-.253	-.057	-.039	-.275
Relations	3	.311*	-.112	-.128	-.051	-.201	-.182	.109	.009	-.160
	4	.192	-.144	-.276	-.039	-.30	-.271	.177	-.146	-.239
	R	-.002	-.080	-.182	-.160	-.194	-.090	-.007	-.150	-.134

N = 49

* = $p < .05$

** = $p < .01$

Table 7.8

Least-squares Estimates of Correlations of Estimated Ability
Factors and Correlations of Extension Variables with
Response Class Frequencies Based on Semantic Relations,
Trial 4 and Reminescence, Condition C

		Factors				Extension Variables				
Response Class	Trial	Fi	Fe	Rs	Cv	Cs	Cf	Ms	Ma	V
Veridical										
Semantic	4	.102	.200	.372*	.313*	.225	.061	.278	.353*	.098
Relations	R	-.029	.205	.505**	.030	.392**	.104	.260	.208	.084
Over-generalized										
Semantic	4	.188	.488**	-.109	.015	.034	-.169	-.089	-.041	-.066
Relations	R	.365*	.277	.284	.052	-.034	-.107	.071	.079	.170
Pseudo-discriminated										
Semantic	4	-.188	.021	.224	-.161	-.050	.133	.093	-.073	.011
Relations	R	.059	.271	-.012	-.223	.098	-.240	-.056	-.007	-.241
Inferred										
Semantic	4	.170	.078	.075	.025	-.061	.014	.098	.023	.061
Relations	R	.276	.145	.211	.400**	.066	.405**	.009	.089	.222
Elaborative										
Semantic	4	-.067	-.031	-.443**	-.291	-.334*	.047	-.148	-.286	.150
Relations	R	.270	-.006	-.302*	-.306*	-.121	.014	-.004	-.085	.149

N = 45

* = p < .05
** = p < .01

correlated with elaborative relations under all conditions. Since it was also shown in Chapter 6 that inferred relations were acquired at input, these results would appear to indicate that the generation of relational structures (other than those which are elaborative) in comprehending and remembering a text *necessarily* involves inferential operations on the semantic content of the text. Included in the preceding statement are those relations which were explicitly coded in the text. These results also indicate independently of the results on mean frequencies of response classes that the effect of the contexts was in part to induce generative reasoning processes. The low correlations of reasoning with inferred relations under condition A deserve some comment. One possible explanation of this result is that the semantic relational information which is scored as "inferred" under condition A, is not generated by the same sort of "formal" operations as the information so scored under condition B. Thus, inferred semantic information which is generated under the "normal" contextual condition (A) may be "presuppositional" in nature. The zero correlation of reasoning with inferred relations on trial 4 under the incidental memory condition (C) probably reflects the fact that by trial 4, the process of *generation* of inferred information is largely complete and the subjects are concentrating on retrieving previously stored semantic information.

The fact that such large positive correlations of measures of comprehension with reasoning were obtained is of extreme interest. Most studies of the relationship of comprehension with abilities have employed standard intelligence tests which include verbal comprehension tasks. It appears that very few studies have found relationships between reasoning measures and measures of comprehension which cannot be explained on the basis of common verbal content. Two studies in particular appear to indicate a relationship between reasoning abilities and performance on comprehension tests. The first (Spearritt, 1962) consisted of a factor analysis of a battery of 34 tests, including measures of listening comprehension, reading comprehension, inductive and deductive reasoning, attention, meaningful and rote memory, memory span, and the STEP listening test given to 300 sixth graders. He was able to identify a factor of "listening comprension" which was positively correlated with factors of verbal comprehension, inductive reasoning, and memory span. The second study, by Hartootunian (1966) attempted to predict reading achievement (measured by the California Achievement Test) from fifteen tests which measured six factors: word fluency, ideational fluency, conceptual foresight, speed of closure, flexibility of closure, judgment and evaluation, and one global measure: the California Test of Mental Maturity. "Conceptual foresight" was measured by two tests: Seeing Problems and Missing Facts. The latter test required the subject to see what facts were needed to solve arithmetic problems. Two other tests, Critical Thinking and Best Answer, both measures of the "judgment and evaluation" factor, required (respectively) seeing which inferences from a set were logical and choosing best answers to practical questions reflecting evaluative skill. Subjects were 513 seventh and eighth graders from two suburban schools. In predicting reading scores by multiple regression, the highest weights were given to Missing Facts, to the two measures of "judgment and evaluation," and to one test of word fluency. However, the global nature of the comprehension scores used in these studies makes interpretation of these findings difficult. The present results should serve to illustrate the kind of information which can be obtained concerning sources of individual differences when specific well-defined "comprehension" measures are employed.

Results pertinent to the effects of differences in efficiency on generating semantic information, on the types and amount of acquired semantic information are found in column 1 of Tables 7.6-7.8. The ideational fluency factor reflects the accessibility of stored semantic information and the ability to retrieve or generate semantic information in situations which vary in the degree to which the generated information is constrained by the task. Notice first that the correlation of this factor with veridical relations increases with repeated exposure to the text for both conditions A and B (with a higher level of correlation for condition A). Apparently, veridical semantic relations are required in a relational structure which is gradually built up and which includes generated (presuppositional?) structural elements such that facility in generating these structural elements is related to the amount of veridical semantic information which is acquired. There also appears to be a positive relationship of ideational fluency with frequencies of overgeneralized semantic relations, the correlations decreasing with repeated exposures to the test (and decreasing more under condition A). These positive correlations probably reflect the same factors as do the positive correlations with veridical relations; the decrease probably reflects the fact that there is much less growth in semantic relations involving overgeneralized concepts than in veridical semantic relations (cf. Tables 5.2 and 5.6). The correlations of ideational fluency with inferred relations decrease for condition A and are generally small and insignificant for both conditions (except for trial 1 and condition A). The differences between conditions A and B in the trial 1 correlation probably reflects the different nature of relations scored as inferred under the two conditions. Judging from the correlations of the ideational fluency factor with frequencies of elaborative semantic relations, efficiency in generating semantic information is important in predicting the extent of elaborative information which is produced only after repeated trials under condition B. This result appears to indicate that the task does not require enough in the way of unconstrained generation of semantic information to make the efficiency of these processes a major factor in determining performance.

Correlations of the expressional fluency factor with veridical and overgeneralized semantic relations are generally positive and significant, especially under conditions B and C and for measures obtained on later trials; correlations with subject-generated inferred relations (and pseudodiscriminated relations which include subject-generated elements) are also significant on the last trial. Efficiency in expressing acquired semantic information thus appears to be a limiting factor as more information is acquired and for response classes having high frequencies of occurrence. The closure factors include measures of speed (Cs) and flexibility (Cf) in identifying and maintaining a visual pattern, and in identifying letter patterns embedded in a sequence of letters (Cv). All of these measures involve the recognition of a "figure" contained in an input configuration; Cv is most similar to pattern identification in processing discourse since it involves letter patterns which are embedded in a sequence (and hence involve sequential scanning). Thus it is not surprising that the closure factors are related to the acquisition of veridical and overgeneralized semantic relations. The fact that this relationship is found only under conditions B and C is presumably related to effects of the increased processing load imposed by conditions B and C, since it is well-known that the difficulty of closure tasks is related to the distracting properties of the pattern in which a figure is embedded.

It remains to consider possible differences in acquired semantic information which are related to memory processes and vocabulary size. First, the capacity of the rehearsal buffer (as measured by auditory letter span) is generally not an important source of individual differences in acquired semantic information. If associative memory is taken as a measure of efficiency in rote memory tasks, rote memory appears to be important only in the acquisition of veridical information on later trials for condition A and for the incidental memory condition. These are just the conditions which appear most likely to produce rote retrieval strategies. Finally, vocabulary shows significant correlations with the acquisition of veridical semantic relations under contexts A and B and these are larger under condition A. Context-related differences also occurred in predicting inferred semantic relations from vocabulary. This last result further suggests that the "inferred relations" produced under condition A were different from the problem-related inferences produced under Condition B. Presumably, these relations produced under condition A are presuppositions obtained in part from expanding and operating upon word meanings.

7.3 Effects of Contextual Conditions on Strategy Choice

Qualitative sources of individual differences in mode of information processing are the subject of the remaining two sections of this chapter. This section will be concerned with presenting a classification of the strategies studied and with identifying specific-strategy statements for which context-induced differences were obtained. The next section will inquire into the manner in which these specific strategies combine in defining major characteristic processing sequences in discourse comprehension and semantic memory by analzing the dependence structures of the strategy measures. Context produced differences in these structures will also be studied. In general, if specific strategies are found to combine into interpretable "processing sequences", this will constitute evidence for important qualitative differences among individuals in discourse comprehension. If such a result is obtained, then qualitative differences among individuals in a less homogenous population would be expected to be even greater.

The method used to measure extent of use of particular strategies in acquiring and remembering information presented in a discourse has already been described in Chapter 5. The method involves presenting a subject with a sentence sampled from the discourse and asking the subject to indicate which of a set of statements of possible strategies apply to describe the strategy he used in acquiring the semantic information contained in the sentence. Previous experience has shown that in relatively protracted learning tasks, subjects can provide reliable information using this procedure (where reliability is assessed by obtaining strategy judgments for a set of "target items", obtaining pooled scores for each strategy statement for random halves of the items, and correlating the resulting part scores (Frederiksen, 1969). The strategy statements presented to the subjects in the present study represent three principal categories of information processing activities: (1) selection strategies (S), (2) retrieval strategies (R), and (3) generative operations (G). The list of strategy statements of Table 7.9 (and all subsequent tables) identifies which categories of processing activities are involved in each strategy. Selection strategies include: attentional strategies (shifting attention and attention to parts), selection of an entire surface sequence (rote memory), semantic selection (particular ideas, unusual ideas), and inferential selection (central ideas, most important ideas). Retrieval strategies involve strategies for the retrieval of semantic information from a stored semantic network and include: undirected search (no particular strategy), directed search (key words by rote, central ideas, details, ideas in sequence, reordered, most important first and expository order), and inferential retrieval strategies (unstated relationships). Generative operations include: inferential processes (classification, previous knowledge, unstated relationships) and elaborative processes (images, associations, illustrations, elaboration). Three statements refer to general characteristics of information-processing strategies: shifted strategies, systematic method, and noticed effectiveness. It should be noted that these statements refer primarily to the semantic memory aspects of the base comprehension task, i.e. in operations occurring during recall. The reason for this is that processes occurring during input should not be as readily identifiable by the subjects as coherent strategies.

Mean numbers of propositions (out of ten) for which subjects indicated that each strategy was employed are presented in Table 7.9 for contextual conditions A, B, and C; by sex and pooled over sex. In pooled within-group standard deviation may be used as an estimate of the common within-group standard deviation of each measure place confidence limits on the means. Analyses of variance for each strategy measure are summarized in Table 7.10. It is apparent from these results that with the exception of associations, all effects of the conditions involved retrieval strategies; some (but not all) of the differences appear to be produced mainly by the incidental memory condition. Thus, undirected search strategies are reported to occur to a much greater extent under the incidental memory condition, while rote strategies (key words by rote, ideas in sequence) occur to a much lesser extent under the incidental memory condition. Reordering of semantic elements in retrieval was reported to occur to a much greater extent under the incidental condition. It is interesting that expository ordering was reported as a strategy, and that the groups were ordered C<A<B in terms of this strategy measure. Significant differences among condition also occurred with respect to generation of associations in the same order (C<A<B). The suggestion is that with respect to some memory strategies, the incidental memory condition is closer to the incidental problem solving condition (A). The absence of differences due to conditions in generation and selection strategies is also interesting, suggesting perhaps that these strategies reflect more the surface and semantic properties of a discourse than they do contextual conditions. Significant sex effects were observed only for undirected retrieval (no particular strategy), the males' scores exceeding the females' under each condition. No significant interactionsof condition with sex were found.

7.4 Structural Analyses of Strategies

Intercorrelations of the twenty-three strategy statements were computed separately for each group and are presented in Tables 7.11-7.13 for conditions A-C respectively. Substantial differences in these correlations are apparent across the three conditions. Since interpretation of differences in these tables across conditions is extremely difficult due to the large numbers of measures, and since we want to determine whether individual differences in reported strategy usage are such that specific strategies group into interpretable characteristic sequences of processing operations, the information provided by each of these matrices concerning the dependence structure of the strategy measure was analyzed. Each of these correlation matrices was analyzed by fitting a linear factor model with extension variables (cf. Table 7.2) to each correlation matrix. The technique used to analyze each matrix involved, first, obtaining principal components of the correlation matrix and rotating the resulting factors using orthogonal varimax. Then small factor loadings were fixed to be exactly zero and the resulting model was fit using Jöreskog's (1970) program to obtain least-squares estimates of all parameters. Then the matrix of residuals was computed by subtracting the correlations reproduced by the model from the sample values. Large residuals were then located by inspection and the model was adjusted to obtain a better fit. Least-squares estimates of parameter values obtained for the best-fitting models obtained for each correlation matrix are reported in Tables 7.14-7.16 (in conditions A, B, and C respectively). These results, obtained by exploratory analysis, can be used as structural hypotheses in subsequent confirmatory studies. Let us now consider the results obtained for each contextual condition in turn, and then compare the results across conditions.

Consider first the parameter values reported in Table 7.14 for condition A. Table 7.14(a) reports the factor loadings of the strategy measures (regression weights of tests on factors) and standard

Table 7.9

Means and Pooled Within-Groups Standard Deviations of Strategy Measures, Conditions A, B, and C, Males, Females, and Pooled Over Sex

Strategy Measure	Condition A			Condition B			Condition C			Pooled Within-Group Standard Deviation
	male	female	pooled	male	female	pooled	male	female	pooled	
1. No particular strategy (R)	3.56	2.52	2.91	3.62	2.91	3.29	6.41	3.70	5.02	3.69
2. Key words by rote (R)	3.61	3.83	3.74	4.35	5.04	4.67	1.95	2.70	2.33	3.78
3. Particular ideas (S)	4.67	4.41	4.51	4.50	3.91	4.22	3.59	4.39	4.00	3.87
4. Central ideas (R)(S)	6.00	5.24	5.53	6.00	5.35	5.69	4.77	5.30	5.04	4.00
5. Details (R)	3.89	3.41	3.60	3.77	3.48	3.63	2.77	2.57	2.67	3.24
6. Ideas in sequence (R)	4.89	3.86	4.26	4.81	5.26	5.02	.77	1.83	1.31	3.76
7. Reordered (R)	.83	1.03	.96	1.62	.83	1.24	3.23	3.35	3.29	3.15
8. Most Important Ideas First (R)(S)	2.89	3.48	3.26	3.12	2.83	2.98	3.09	4.48	3.80	3.53
9. Unstated Relationships (R)(G)	1.89	2.21	2.09	2.46	1.74	2.12	3.09	2.48	2.78	2.95
10. Unusual Ideas (S)	1.89	2.07	2.00	2.65	2.57	2.61	2.55	1.83	2.18	1.93
11. Shifted Attention (S)	1.67	1.55	1.60	2.04	1.78	1.92	2.18	1.91	2.04	2.78
12. Visual Images (G)	3.44	2.86	3.09	4.54	3.65	4.12	3.82	2.52	3.16	3.72
13. Shifted Strategies	.44	.97	.77	.88	1.43	1.14	.55	.52	.53	1.38
14. Attention to parts (S)	4.44	3.21	3.68	4.69	3.78	4.27	4.32	3.39	3.84	4.37
15. Formed Associations (G)	2.89	3.38	3.19	4.08	3.52	3.82	2.05	2.35	2.20	2.89
16. Classification (G)	1.39	1.21	1.28	1.35	1.74	1.53	.55	1.87	1.22	2.67
17. Previous Knowledge (G)	3.28	3.28	3.28	5.50	3.13	4.39	4.55	3.17	3.84	3.85
18. Illustration (G)	1.06	1.00	1.02	1.73	1.39	1.57	1.18	.57	.87	2.01
19. Systematic Method	.61	.45	.51	1.42	.78	1.12	.36	.39	.38	1.92
20. Noticed Effectiveness	.50	.76	.66	1.31	1.09	1.20	.73	.48	.60	1.51
21. Rote memory (S)	3.67	2.86	3.17	2.12	3.35	2.69	1.95	1.61	1.78	3.45
22. Elaboration (G)	2.56	2.17	2.32	3.35	3.09	3.22	1.73	2.83	2.29	2.77
23. Expository order (R)	2.06	2.14	2.11	3.73	2.09	2.96	1.45	.65	1.04	3.76

(R) = Retrieval Strategy
(S) = Selection Strategy
(G) = Generative Operation

Table 7.10

Analyses of Variance of Strategy Measures Testing Main Effects of Conditions, Sex, and Interaction, Conditions A, B, and C

Strategy Measure	Conditions F	Sex F	Interaction F
1. No particular strategy (R)	4.06*	5.60*	.98
2. Key words by rote (R)	4.62*	.73	.07
3. Particular ideas (S)	.23	.00	.40
4. Central ideas (R)(S)	.36	.19	.36
5. Details (R)	1.35	.35	.02
6. Ideas in sequence (R)	12.89***	.06	.91
7. Reordered (R)	7.53***	.08	.36
8. Most Important Ideas First (R)(S)	.66	.88	.66
9. Unstated Relationships (R)(G)	.88	.46	.43
10. Unusual Ideas (S)	1.30	.40	.64
11. Shifted Attention (S)	.29	.20	.01
12. Visual Images (G)	1.00	2.12	.10
13. Shifted Strategies	2.60	2.21	.63
14. Attention to parts (S)	.13	1.90	.02
15. Formed Associations (G)	3.63*	.03	.44
16. Classification (G)	.20	1.27	.91
17. Previous Knowledge (G)	.85	3.62	1.10
18. Illustration (G)	1.53	.97	.22
19. Systematic Method	1.88	.62	.38
20. Noticed Effectiveness	2.33	.07	.40
21. Rote memory (S)	2.13	.00	1.13
22. Elaboration (G)	1.66	.10	1.00
23. Expository order (R)	2.86	1.52	.61

* = $p < .05$
** = $p < .01$
*** = $p < .001$

Table 7.11 (a)

Intercorrelations of Strategy Measures, Condition A

Strategy Measure	1	2	3	4	5	6	7	8	9	10
1. No Particular strategy (R)	-									
2. Key words by rote (R)	-.311	-								
3. Particular ideas (S)	-.321	.587	-							
4. Central Ideas (R)(S)	-.412	.145	.324	-						
5. Details (R)	-.157	.445	.588	.031	-					
6. Ideas in sequence (R)	-.250	.279	.632	.468	.408	-				
7. Reordered (R)	-.037	.031	.124	.089	-.032	-.006	-			
8. Most Important Ideas First (R)(S)	-.295	.226	.368	.475	.143	.204	.295	-		
9. Unstated Relationships (R)(G)	-.219	.148	.260	.399	.135	.297	.340	.125	-	
10. Unusual Ideas (S)	-.196	.329	.297	.135	.426	.080	.000	.157	.419	-
11. Shifted Attention (S)	-.230	.355	.314	.291	.023	.091	.487	.160	.218	.099
12. Visual Images (G)	-.302	.179	.293	.248	.297	.145	.296	.355	.191	.136
13. Shifted Strategies	-.159	.027	.243	-.057	.137	.076	.544	.132	.215	.126
14. Attention to parts (S)	-.149	.024	.311	.273	.166	.201	.216	.189	.112	.068
15. Formed Associations (G)	-.181	.139	.345	.305	.134	.351	.185	.329	.448	.023
16. Classification (G)	.068	.284	.398	.188	.385	.338	.060	.277	.167	.300
17. Previous Knowledge (G)	-.309	.230	.326	.513	.173	.255	.316	.411	.458	.094
18. Illustration (G)	-.207	.095	.171	.232	.067	.116	.628	.244	.473	.077
19. Systematic Method	.204	.135	.246	.043	.259	.183	.581	.220	.227	-.068
20. Noticed Effectiveness	-.074	.133	.478	.039	.423	.188	.305	.042	.137	.192
21. Rote memory (S)	-.192	.730	.292	-.069	.330	.194	.126	.063	-.102	.105
22. Elaboration (G)	-.121	.110	.216	.356	.134	.097	.404	.427	.427	.334
23. Expository order (R)	-.082	.327	.292	.123	.081	.101	-.059	.260	-.015	.004

Table 7.11 (b)

Intercorrelations of Strategy Measures, Condition A

Strategy Measure	11	12	13	14	15	16	17	18	19	20	21	22
11. Shifted Attention (S)	1.000											
12. Visual Images (G)	.237	1.000										
13. Shifted Strategies	.430	.144	1.000									
14. Attention to parts (S)	.438	.263	.201	1.000								
15. Formed Associations (G)	.084	.262	.178	-.009	1.000							
16. Classification (G)	-.128	.159	.182	-.052	.437	1.000						
17. Previous Knowledge (G)	.278	.640	-.005	.410	.338	.251	1.000					
18. Illustration (G)	.469	.503	.416	.270	.355	.124	.554	1.000				
19. Systematic Method	.245	.410	.271	.021	.276	.340	.335	.507	1.000			
20. Noticed Effectiveness	.390	.195	.615	.145	.139	.174	.052	.197	.214	1.000		
21. Rote memory (S)	.296	.065	.121	-.067	-.016	.147	-.028	.031	.266	.043	-	
22. Elaboration (G)	.363	.286	.254	.232	.297	.126	.240	.319	.381	.165	.030	-
23. Expository order (R)	.096	-.118	.093	-.026	.119	.197	.071	-.072	-.109	-.022	.217	-.150

Table 7.12 (a)

Intercorrelations of Strategy Measures, Condition B

Strategy Measure	1	2	3	4	5	6	7	8	9	10
1. No particular strategy (R)	-									
2. Key words by rote (R)	.166	-								
3. Particular ideas (S)	-.160	.295	-							
4. Central ideas (R)(S)	-.074	.239	.135	-						
5. Details (R)	-.207	.326	.606	.173	-					
6. Ideas in sequence (R)	-.234	.190	.309	.341	.384	-				
7. Reordered (R)	-.028	-.060	.283	.321	.198	-.124	-			
8. Most Important Ideas First (R)(S)	.001	.099	.229	.428	.174	.270	.236	-		
9. Unstated Relationships (R)(G)	-.097	.137	.366	.025	.313	.096	-.006	.191	-	
10. Unusual Ideas (S)	-.164	-.039	.353	-.003	.148	-.166	.436	-.114	-.061	-
11. Shifted Attention (S)	-.148	.349	.235	.178	.293	.363	.247	.126	.258	.040
12. Visual Images (G)	-.042	-.014	.044	.332	.048	.058	.256	-.096	-.067	.299
13. Shifted Strategies	.019	.140	.039	-.016	.092	.226	-.117	-.014	.117	-.024
14. Attention to parts (S)	.132	.453	.314	.135	.296	.118	.144	.098	.318	.135
15. Formed Associations (G)	-.120	.218	.588	.099	.490	.104	.164	.286	.476	.098
16. Classification (G)	-.145	.319	.547	.257	.528	.498	.026	.377	.360	-.020
17. Previous Knowledge (G)	-.100	-.126	.101	.361	.142	.413	.319	.147	.109	.044
18. Illustration (G)	-.296	-.195	.195	.134	.076	-.157	.456	.108	-.035	.366
19. Systematic Method	-.234	-.078	.047	.416	.291	.302	.050	-.114	-.122	.176
20. Noticed Effectiveness	.096	.256	.095	.119	.267	.274	-.094	-.063	.176	-.043
21. Rote memory (S)	.051	.511	.070	-.005	.253	.021	.022	-.004	-.142	.034
22. Elaboration (G)	-.186	.077	.339	.197	.179	.199	.040	.041	.471	.055
23. Expository order (R)	-.198	.088	.081	.423	.129	.253	.174	.294	.286	.231

Table 7.12 (b)

Intercorrelations of Strategy Measures, Condition B

Strategy Measure	11	12	13	14	15	16	17	18	19	20	21	22
11. Shifted Attention (S)	-											
12. Visual Images (G)	-.038	-										
13. Shifted Strategies	.209	-.142	-									
14. Attention to parts (S)	.467	-.097	.273	-								
15. Formed Associations (G)	.218	.032	.035	.276	-							
16. Classification (G)	.350	-.003	.180	.220	.457	-						
17. Previous Knowledge (G)	.164	.521	-.022	-.108	.055	.112	-					
18. Illustration (G)	-.064	.512	-.220	-.135	.227	-.011	.222	-				
19. Systematic Method	.004	.348	-.017	-.051	.021	.209	.385	-.112	-			
20. Noticed Effectiveness	.163	.214	.510	.245	.039	.112	.219	-.132	.218	-		
21. Rote memory (S)	.303	-.141	.373	.313	.027	.022	-.100	-.207	.035	.314		
22. Elaboration (G)	.093	.182	.066	.239	.375	.236	.271	.359	-.116	.147	-.104	-
23. Expository order (R)	.122	.408	.105	.125	-.001	.376	.394	.187	.354	.293	-.129	.196

Table 7.13 (a)

Intercorrelations of Strategy Measures, Condition C

Strategy Measure	1	2	3	4	5	6	7	8	9	10
1. No particular strategy (R)	-									
2. Key words by rote (R)	-.171	-								
3. Particular ideas (S)	.075	.250	-							
4. Central ideas (R)(S)	.034	.076	.228	-						
5. Details (R)	.078	.410	.341	.313	--					
6. Ideas in sequence (R)	-.304	.051	.033	.226	.240	-				
7. Reordered (R)	.177	-.085	.144	-.008	-.177	-.125	-			
8. Most Important Ideas First (R)(S)	.085	-.062	.171	.453	-.018	.187	.215	-		
9. Unstated Relationships (R)(G)	.034	-.165	.060	.458	-.135	.115	.005	.612	-	
10. Unusual Ideas (S)	-.293	-.050	-.054	-.087	.021	.074	-.284	-.305	-.013	-
11. Shifted Attention (S)	.233	.061	.329	.248	.205	-.072	.124	.593	.278	-.126
12. Visual Images (G)	-.199	-.068	-.236	-.153	-.082	-.016	-.060	-.162	-.045	.386
13. Shifted Strategies	-.173	.426	.126	.021	.258	.016	-.045	-.045	-.076	.066
14. Attention to parts (S)	.290	.356	.380	.246	.410	.035	-.032	.316	.084	-.139
15. Formed Associations (G)	-.321	.386	.151	.133	.157	.510	-.007	.083	.135	.165
16. Classification (G)	-.261	.004	.360	-.048	-.027	.070	.225	-.053	-.137	-.021
17. Previous Knowledge (G)	.002	.110	.439	.214	.062	-.079	.103	.147	.291	.060
18. Illustration (G)	-.216	.346	.167	.237	.158	.042	-.166	-.010	-.021	.475
19. Systematic Method	-.094	.380	.056	.182	.072	.447	.028	.230	.131	-.113
20. Noticed Effectiveness	-.153	.241	.233	.195	.377	.141	-.127	.035	-.049	.427
21. Rote memory (S)	.105	.186	.028	-.225	-.069	-.040	-.082	-.051	-.228	-.167
22. Elaboration (G)	-.357	.360	.050	.169	.057	.334	-.018	.243	.363	.167
23. Expository order (R)	.141	.087	.268	.234	.174	.237	-.126	.454	.337	-.218

Table 7.13 (b)

Intercorrelations of Strategy Measures, Condition C

Strategy Measure	11	12	13	14	15	16	17	18	19	20	21	22
11. Shifted Attention (S)	-											
12. Visual Images (G)	-.135	-										
13. Shifted Strategies	.123	-.005	-									
14. Attention to parts (S)	.579	-.197	.209	-								
15. Formed Associations (G)	-.054	.049	.471	.209	-							
16. Classification (G)	-.119	.121	.022	-.086	-.019	-						
17. Previous Knowledge (G)	.382	.061	.214	.343	.170	.107	-					
18. Illustration (G)	-.014	.297	.246	.192	.085	.164	.307	-				
19. Systematic Method	.001	.173	.233	.191	.446	.254	.010	.363	-			
20. Noticed Effectiveness	.026	.023	.358	.186	.218	.104	.317	.596	.198	-		
21. Rote memory (S)	-.056	-.114	.030	.228	.074	-.096	-.209	-.106	.105	-.105	-	
22. Elaboration (G)	-.148	.036	.169	.097	.598	-.038	-.020	.172	.440	.149	.005	-
23. Expository order (R)	.375	-.067	.122	.364	.190	.046	.177	.068	.393	.027	.124	.236

deviations of specific parts of each measure. Note that interpretations of the factors obtained using the present model-fitting method of analysis are clearer than in conventional factor analysis, since many factor loadings have been fixed to be precisely zero. Furthermore, the model which is fit statistically to the data thus corresponds exactly to the model which is interpreted. Factor one involves all of the generative strategies except classification, and also involves related selection strategies, and hence refers to a use of generative operations. Factor two involves the generative operations classification: association, previous knowledge and unstated relationships; and sequential selection of central ideas. Thus factor two reflects inferential selection strategies and generative operations and may be described as involving inferential organization of central ideas. Factor three appears to represent unstable selecton strategies. Factors four and five appear to represent rather specific retrieval strategies: retrieval of selected details in serial order and rote memory respectively. Factor six appears to represent a strategy involving the generation of unstated relations involving unfamiliar ideas, and seven involves attention to parts (as opposed to classification operations on the structure as a whole). Analysis of the structural relationships among selection, retrieval, and generative strategy measures obtained under condition A (with repeated exposure) does appear to result in strategy combinations which include very general classes of operations (generative operations), organizational processes involving the semantic structure as a whole (organization of central ideas), aspects of information selection, and specific retrieval strategies. Estimated intercorrelations of the factors and correlations of the factors with the extension variables are reported on Tables 7.14 (b) and (c). In general, these strategy-factors appear to be relatively independent of one another.

Inspection of the results reported in Tables 7.15 and 7.16 indicates that interpretable combinations of strategy measures occur for conditions B and C as well as for condition A. Two strategy-factors occur which are common to all three contextual conditions: attention to parts and rote memory. A factor representing generative operations occurs under condition B (factor five) as well as condition A as does a factor involving unstable strategies. In addition, two strategy combinations occur under both conditions B and C: classification of selected ideas and elaboration of unfamiliar ideas. Also occurring for conditions B and C are strategy combinations reflecting inferential operations: inferential selection (factor six, condition B) and inferential operations (factor one, condition C). This latter result appears to reflect an effect of the context-induced inferential operations described in previous chapters. Finally, two additional strategy combinations occur under condition C: a retrieval strategy involving retrieval of selected ideas in serial order (factor seven, perhaps corresponding to factor four obtained under condition A); and a factor which appears to involve the elaboration of lexical elements. In general, it appears as if there are systematic qualitative differences among individuals as well as quantitative differences related

Table 7.14

Least-Squares Estimates of Parameter Values for Model Fit to Matrix of Intercorrelations of Strategy Measures, Condition A

Factor Pattern Matrix
(Matrix of Regression Weights of Tests on Factors, Λ_1) (a)

Strategy Measure[1]	Factor Loading 1	2	3	4	5	6	7	Standard Deviation of Specific Part Ψ_1
2. Key words by rote (R)	.0*	.0*	.0*	.361	.718	.0*	.0*	.438
3. Particular Ideas (S)	.0*	.109	.0*	.954	.0*	.0*	.0*	.003
4. Central Ideas (R)(S)	.234	.653	.0*	.0*	.0*	.089	.0*	.669
5. Details (R)	-.070	.0*	.0*	.676	.110	.179	.0*	.712
6. Ideas in Sequence (R)	.0*	.332	.0*	.452	.0*	.0*	.0*	.754
7. Reordered (R)	.603	.0*	.442	-.252	.0*	.0*	.0*	.591
8. Most Important Ideas First (R)(S)	.341	.443	.0*	.0*	.0*	.0*	.0*	.783
9. Unstated Relationships (R)(G)	.481	.250	.0*	.0*	.0*	.398	.0*	.732
10. Unusual Ideas (S)	.0*	.0*	.0*	.464	.0*	.951	.0*	.002
11. Shifted Attention (S)	.303	-.050	.558	.0*	.427	.0*	.543	.551
12. Visual Images (G)	.566	.0*	.0*	.156	.0*	.0*	.0*	.774
13. Shifted Strategies	.0*	.0*	.933	.0*	.0*	.0*	.0*	.359
14. Attention to Parts (S)	.205	.0*	.235	.256	.0*	.0*	.458	.826
15. Formed Associations (G)	.350	.370	.0*	.0*	.0*	.0*	.0*	.822
16. Classification (G)	.0*	.572	.0*	-.010	.0*	.072	-.776	.540
17. Previous Knowledge (G)	.546	.399	.0*	.0*	.0*	.0*	.0*	.659
18. Illustration (G)	.880	-.144	.0*	.0*	.0*	.0*	.0*	.517
20. Noticed Effectiveness	.0*	.0*	.551	.259	.0*	.0*	.0*	.739
21. Rote memory (S)	.0*	.0*	.0*	.0*	.892	.0*	.0*	.452
22. Elaboration (G)	.564	.074	.0*	.0*	.0*	.329	.0*	.763

1. Strategy measures (1.), (19.), and (23.) were treated as extension variables

* denotes parameter values fixed by the model.

(R) = Retrieval Strategy

(S) = Selection Strategy

(G) = Generative Operation

Table 7.14 (continued)

Intercorrelations of Factors
(Φ_{11} Matrix) (b)

Factor	1	2	3	4	5	6	7
1. Generative Operations	1.-*						
2. Organization of Central Ideas	.247	1.-*					
3. Unstable Selection Strategies	.360	-.185	1.-*				
4. Retrieval of Selected Details in Serial Order	.320	.389	.294	1.-*			
5. Rote memory	.074	-.011	.040	.313	1.-*		
6. Generation of Unstated Relations Involving Unfamiliar Ideas	-.081	-.082	.054	-.130	.014	1.-*	
7. Attention to Parts	-.077	.243	-.355	-.288	-.264	-.055	1.-*

Correlations of Extension Variables with Factors
(Φ_{12} Matrix) (c)

Strategy Measure	1	2	3	4	5	6	7
1. No Particular Strategy (R)	-.259	-.378	-.046	-.293	-.214	-.027	-.226
19. Systematic Method	-.088	.318	.048	.174	.293	-.128	-.050
23. Expository Order (R)	.667	-.036	.324	.275	.217	-.172	-.495

Least-squares criterion = 2.3308, d.f. = 140

Table 7.15

Least-Squares Estimates of Parameter Values for Model Fit to Matrix of Intercorrelations of Strategy Measures, Condition B

Factor Pattern Matrix
(Matrix of Regression Weights of Tests on Factors, Λ_1) (a)

Strategy Measure[1]	Factor Loading 1	2	3	4	5	6	7	8	Standard Deviation of Specific Part Ψ_j
2. Key Words by Rote (R)	.307	.0*	.587	.0*	.0*	.0*	.0*	.0*	.703
3. Particular Ideas (S)	.838	.0*	.0*	.257	.249	.0*	.0*	.0*	.569
4. Central Ideas (R)(S)	.0*	.507	.0*	.0*	.0*	.296	.0*	.0*	.728
5. Details (R)	.734	.0*	.053	.0*	.0*	.0*	.0*	.0*	.666
7. Reordered (R)	.0*	.0*	.0*	.822	.0*	.769	.0*	.0*	.583
8. Most Important Ideas First (R)(S)	.0*	.0*	.0*	.0*	.0*	.676	.0*	.0*	.737
9. Unstated Relationships (R)(G)	.521	.0*	.0*	.0*	.337	.0*	.0*	.0*	.796
10. Unusual Ideas (S)	.380	.0*	.0*	.781	.0*	.0*	.0*	.0*	.643
11. Shifted Attention (S)	.0*	.0*	.0*	.0*	.0*	.0*	.673	.0*	.740
12. Visual Images (G)	.0*	.575	.0*	.438	.0*	.0*	.0*	.0*	.694
13. Shifted Strategies	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.603	.797
14. Attention to Parts (S)	.0*	.0*	.0*	.0*	.0*	.0*	.694	.0*	.720
15. Formed Associations (G)	.655	.0*	.0*	.0*	.399	.0*	.0*	.0*	.664
16. Classification (G)	.619	.037	.0*	.0*	.0*	.192	.0*	.0*	.669
17. Previous Knowledge (G)	.0*	.718	.0*	.036	.064	-.053	.0*	.0*	.730
18. Illustrations (G)	.0*	.522	.0*	.579	.641	.0*	.0*	.0*	.471
20. Noticed Effectiveness	.0*	.0*	.0*	.0*	.0*	.0*	.0*	.845	.535
21. Rote Memory (S)	.0*	.0*	.805	.0*	.0*	.0*	.0*	.0*	.593
22. Elaboration (G)	.272	.344	.0*	.0*	.517	.0*	.0*	.0*	.771
23. Expository Order (R)	.0*	.681	.0*	.0*	.0*	.0*	.0*	.0*	.732

1. Strategy measures (1.), (6.), and (19.) were treated as extension variables.

* denotes parameter values fixed by the model.

(R) = Retrieval Strategy

(S) = Selection Strategy

(G) = Generative Operation

Table 7.15 (continued)

Intercorrelations of Factors
(Φ_{11} Matrix) (b)

Factor	1	2	3	4	5	6	7	8
1. Classifcation of Selected Ideas	1.-*							
2. Elaboration of Central Ideas	.307	1.-*						
3. Rote Memory	.188	-.112	1.-*					
4. Elaboration of Unfamiliar Ideas	-.283	-.007	-.100	1.-*				
5. Generative Operations	-.056	-.269	-.279	-.076	1.-*			
6. Inferential Selection	.468	.419	.061	-.480	.054	1.-*		
7. Attention to Parts	.601	.118	.602	-.165	-.043	.419	1.-*	
8. Unstable Strategies	.307	.296	.479	-.224	-.249	-.021	.432	1.-*

Correlations of Extension Variables with Factors
(Φ_{12} Matrix) (c)

	Factor							
Strategy Measure	1	2	3	4	5	6	7	8
1. No Particular Strategy (R)	-.162	-.177	.163	-.078	-.150	.020	.028	.086
6. Ideas in Sequence (R)	.528	.520	.033	-.459	-.319	.362	.349	.341
19. Systematic Method	.316	.599	-.072	.068	-.729	-.043	-.034	.161

Least-Squares Criterion = 2.6191, d.f. = 142

to processing efficiency. While the results reported in this chapter leave little doubt that important quantitative and qualitative differences exist among individuals, in the long run, any detailed understanding of sources of individual differences will require a detailed understanding of the sequence of processing operations involved in acquiring semantic information from discourses. Studies of individual differences in discourse processing can both profit from and contribute to knowledge concerning the basic processes involved in acquiring knowledge from discourse.

Table 7.16

Least-Squares Estimates of Parameter Values for Model Fit to Matrix of Intercorrelations of Strategy Measures, Condition C

Factor Pattern Matrix
(Matrix of Regression Weights of Tests on Factors, Λ_1) (a)

Strategy Measure[1]	Factor Loading 1	2	3	4	5	6	7	Standard Deviation of Specific Part Ψ_j
2. Key Words by Rite (R)	.0*	.355	.279	.0*	.310	.0*	.484	.699
3. Particular Ideas (S)	.0*	.0*	.653	.0*	.0*	.624	.0*	.521
4. Central Ideas (R) (S)	.751	.0*	.0*	.0*	.0*	.0*	.465	.717
5. Details (R)	.0*	.0*	.518	.0*	.0*	.0*	.689	.655
6. Ideas in Sequence (R)	.202	.414	.0*	.0*	.0*	.0*	.187	.852
7. Reordered (R)	.0*	.0*	.0*	.0*	.0*	.295	-.449	.880
8. Most Important Ideas First (R)(S)	.782	.0*	.196	.0*	.0*	.0*	.0*	.491
9. Unstated Relationships (R)(G)	.759	.0*	.0*	.0*	.0*	.0*	.0*	.651
10. Unusual Ideas (S)	.0*	.0*	.0*	.602	.0*	.0*	.0*	.799
11. Shifted Attention (S)	.218	.0*	.675	.0*	.0*	.0*	.0*	.625
12. Visual Images (G)	.0*	.0*	.0*	.333	.0*	.0*	.0*	.943
14. Attention to Parts (S)	.318	.0*	.661	.0*	.434	.0*	.451	.549
15. Formed Associations (G)	.0*	.859	.0*	.0*	.0*	.0*	.0*	.513
16. Classification (G)	.0*	.0*	.0*	.0*	.0*	.712	.0*	.702
17. Previous Knowledge (G)	.131	.0*	.459	.365	.0*	.0*	.0*	.809
18. Illustrations (G)	.0*	.0*	.0*	.879	.0*	.0*	.0*	.477
21. Rote Memory (S)	.0*	.0*	.0*	.0*	.609	.0*	.0*	.793
22. Elaboration (G)	.145	.691	.0*	.0*	.0*	.0*	.0*	.685
23. Expository Order (R)	.724	.0*	.156	.0*	.477	.140	.327	.768

1. Strategy measures (1.), (13.), (19.), and (20) were treated as extension variables.

* denotes parameter values fixed by the model

(R) = Retrieval Strategy

(S) = Selection Strategy

(G) = Generative Operation

Table 7.16 (continued)

Intercorrelations of Factors
(Φ_{11} Matrix) (b)

Factor	1	2	3	4	5	6	7
1. Inferential Operations	1.-*						
2. Elaboration of Lexical Elements	.160	1.-*					
3. Alteration to Parts	.359	-.078	1.-*				
4. Elaboration of Unfamiliar Ideas	-.128	.219	-.141	1.-*			
5. Rote Memory	-.388	.101	.109	-.247	1.-*		
6. Classification of Selected Ideas	-.159	.125	-.108	.203	-.185	1.-*	
7. Retrieval of Selected Ideas	-.422	.208	-.240	.392	-.186	.241	1.-*

Correlations of Extension Variables with Factors
(Φ_{12} Matrix) (c)

Strategy Measure	1	2	3	4	5	6	7
1. No Particular Strategy	.086	-.479	.359	-.360	.218	-.265	-.241
13. Shifted Strategies	-.117	.407	.226	.218	.125	.021	.196
19. Systematic Method	.234	.596	-.127	.234	.239	.310	.197
20. Noticed Effectiveness	-.038	.229	.140	.640	-.214	.180	.421

Least-squares criterion = 3.3767, d.f. = 145

PART II

CHAPTER 8

SEMANTICS AND COMPREHENSION

8.1 Introduction

If psychologists are ever to understand how human knowledge is acquired, they are going to have to come to grips with the difficult and elusive problems of semantics. An expansion of the meaning of the preceding statement will have to focus on specifying a meaning for "human knowledge" and a referent for the adverb "how". In fact, problems of semantics are encountered in trying to explain either term. Human knowledge consists of a variety of sorts of information, but certainly includes information which is derived from linguistic expressions but which is not identical to the surface form of those expressions. Furthermore, it is tempting to suppose as a working hypothesis that much of human knowledge is represented in terms of a single "canonical" form and that this single form of representation is derived from linguistic experience. A description of the manner in which human knowledge is acquired must certainly include both a description of the sources of human knowledge and a description of that knowledge which is acquired. Such a description will also consist of an account of the series of operations which result in the acquisition of that knowledge.

Suppose we restrict our attention to the problem of explaining how knowledge is acquired from a single source: a particular English discourse. To make the question "How does a person understand the discourse?" answerable requires that we be able to specify in detail both the structural information which is contained in the discourse and the structural information which is acquired from the discourse. If structural representations of an input discourse and the information resulting when that discourse is understood were available, one could then begin to consider the psychological processes necessary to generate the latter from the former. Since the contents of the human mind are not directly available for our inspection, the obvious place to look for a structural theory of human knowledge is at natural language discourse. Thus, the strategy involves first seeking to develop a semantic representation of natural language discourse (which _is_ available for our inspection), both as a means of specifying the structural characteristics of linguistic inputs and as an hypothetical starting point for a model of human knowledge.

The curious fact is that not until recently has this strategy been adopted by psychologists interested in language comprehension and the acquisition of knowledge from discourse. This strategy _has_ been adopted recently by Crothers (1970, 1971) in his work on memory structures and the recall of discourse and, at least in a preliminary fashion, in recent models of semantic memory (Rummelhart, et al., 1971; Kintsch, 1972; Norman, 1972; Quillian, 1968). This strategy of course has long been adopted at the syntactic level by psycholinguists working in the tradition of generative transformational grammar who were interested primarily in the processing of syntactic information. More recently, computer models of semantic information processing have tended to concentrate on developing either parsing programs or logical components of a processing system. The form in which semantic information is represented in these programs (the propositional structure) has tended to be dictated more by the requirements of the logical component of the system than by semantic characteristics of English discourse. Thus, semantics has tended to "get lost" in between the parser and the logical components which operate on acquired propositional information (cf. Minsky, 1968; Winograd, 1972). In fact, it appears that if a semantic information processing system were built around a semantic model derived from natural language discourse, the logical components in the system would have to be capable of operating on propositional structures which are different in many respects from those handled in current programs. Furthermore, if a computer model were built around an adequate theory of semantic representation, that part of the program which semantically "interprets" syntactically analyzed inputs is also likely to be quite different from the interpretive component of current systems (cf. Schank, 1971). For example, it will be shown in Chapter 9 that many common expressions require structural representations in which not all of the semantic structural information is explicitly marked in the surface structure. Considerations such as these imply that any model which incorporates a realistic semantic model (which is capable of representing English discourse) will have to be capable of generating structural information which is not explicitly represented in the linguistic input.

There is still another reason why a psychology of learning and cognition must come to grips with problems of the semantics of discourse, a reason which motivated many of the developments to be reported in the following two chapters. If we accept the arguments developed in Chapters 1 and 2 for selecting that task to "measure comprehension" which is most general and adopt the base comprehension task as a general paradigm for studies of discourse comprehension and semantic memory, then we are confronted with the problem of developing a scoring system which is capable of representing a subject's verbal responses semantically against a semantic-structural model of an input discourse. Once such a procedure has been developed for the base comprehension task, it may be applied very generally to many situations in which the data consist of verbal protocols. In experimental work, the semantic model has two important functions: in representing formally the semantic characteristics of the task used to study comprehension and in analyzing subjects' verbal responses. A well-defined semantic model is necessary for the former function, even in tasks in which only choice responses are obtained (e.g. in sentence verification, question answering, judgments of semantic acceptability).

In both Crother's (1970, 1971) work and the present work, the problem of developing a semantic representation of discourse has been approached by trying to develop a solution to the scoring problem--to develop a means of representing logico-semantic information acquired from a discourse from an analysis of subjects' free verbal reconstructions of knowledge acquired from a presented discourse. This appears to be a desirable way to approach problems of semantics for three principal reasons. First, in developing a procedure to analyze subjects' recall protocols, one is continually presented not only with a particular discourse to be analyzed, but also with a variety of recall protocols, each of which contains semantic information which is reproduced in paraphrase from the discourse presented to the subjects and semantic information which does not correspond to explicitly presented information but which may be derived from explicitly presented semantic information. In attempting to identify input semantic information in such protocols, one is continually confronted with a variety of surface expressions constituting an "empirical paraphrase set" for each input semantic structure. The problem of semantic analysis involves developing a single structural representation of that semantic information which is common to each member of the paraphrase set. Second, recall protocols obtained from experimental subjects typically contain a large proportion of information which is subject-generated, i.e. which does not correspond to semantic information which was explicitly represented in an input discourse in linguistically coded form. Such information appears to include expressed presuppositions, results of formal inferential operations, expressions of retrieved information corresponding to lexical elements, and sheer elaboration. The apparently universal presence of such information in subjects' protocols suggests that a semantic representation of an input text ought to include some information which is not explicitly marked in the input discourse and, by providing samples of semantic information likely to be generated, recall protocols provide some indication of what inexplicitly coded information should be included in the semantic model of a text and of the relationship of that information to that which is explicitly represented in a text. Finally, if one attempts to develop a semantic structural model as the basis for a scoring procedure for measuring semantic information acquired from a discourse, one is constantly presented with a linguistic "corpus" which has the sometimes unpleasant habit of not fitting easily into a preconceived semantic model.

8.2 Requirements for a Semantic Model

There are a number of requirements which a semantic model must satisfy if it is going to be satisfactory as a model of linguistic inputs, as a model for memory structures, or as the basis for a scoring system. First, a semantic model should not represent the surface structure of a text except insofar as the surface structure uniquely represents a given semantic structure, and it should not be defined in terms of particular surface expressions or sets of surface expressions; rather, a semantic description should be capable of representing each text up to a paraphrase transformation and each element of the semantic structure should be defined independently of any particular rules of expression (cf. Leech, 1969). Note that, formally, this requirement of independence from surface expressions presents us with the following problem. The semantic model rests on decisions with respect to which expressions constitute a paraphrase set. However, a paraphrase set cannot be defined precisely without first having a semantic model and a set of rules of expression. This circularity can be avoided in practice only by relying initially on linguistic intuitions concerning equivalence in "literal meaning" and thus by informally considering what expressional forms are equivalent in literal meaning. A model so constructed must of course eventually be expanded to include a set of rules of expression and a surface grammar to formalize the definitions of what expressions are equivalent in meaning. Only then can the model be subjected to direct empirical validation. However, the experiment of Collins and Quillian (1969) illustrated one way in which a semantic model can be indirectly validated without any consideration of expressional rules. Still another procedure based on statistical dependence properties of measures resulting from semantically analyzed recall protocols will be described in Chapter 10.

A second requirement is that the model be capable of representing discourses consisting of many sentences and that it treat sentence boundaries as purely surface phenomena having no intrinsic semantic significance. A third requirement is that insofar as is possible, a semantic model should seek only to represent those semantic structural relations which a discourse imposes on its lexical elements and to maintain intact lexical elements as elements of the semantic structure. Thus, a semantic model should not attempt to analyze lexical elements; rather a lexical element should be regarded as an entry point to a subject's lexical memory, the meaning of that element being that semantic information which a subject retrieves from this long-term memory store when the lexical designator is used as a starting point from which information is retrieved. This requirement leads to a method of semantic analysis which is substantially different from that advocated by linguists adopting the so-called "generative semantic" approach (cf. Maclay, 1971; Lakoff, 1971). Thus, our ultimate purpose in semantic analysis is not to specify a set of rules which are capable of generating the set of all semantically acceptable texts; rather our purpose is purely representational. The linguistic viewpoint adopted in the present work resembles more the stratificational viewpoint of structural linguistics than any other current school of linguistic thought (cf. Leech, 1969). Just as it has become apparent that derivational tree structures are unlikely as internal representations of the syntactic structure of single sentences, it appears equally unlikely that internal semantic structures have such a structural form. In addition, it is difficult to imagine how derivational tree structures could be suitable for the representation of texts consisting of many sentences. The form of representation adopted in the present work is a graph-structure of the form used in computational linguistic work (Simmons, 1968, 1971), and consists of nodes corresponding to lexical elements which may be connected by directed relations taken from a limited number of defined semantic relations.

In addition to the requirements just outlined, a semantic model must also be well-defined, i.e. all semantic relations, the primitives of the model, must be explicitly and unambiguously defined. A semantic model must also be general enough to be capable of representing semantic information contained in subjects' recall protocols; and it must fit the linguistic data it purports to represent, i.e. together with a set of expressional rules and a surface grammar, it must be capable of generating all members of the paraphrase set for any particular discourse. One might also hope that, as a semantic model is developed and revised, it would be found to be applicable to the semantic analysis of a large number of languages. It would appear that the best place to look for linguistic universals is at the semantic level. At least, this seems to be the working assumption among computational linguists seeking to develop computer translation systems (Simmons, 1971). Note that the requirement that all relational connectives be well-defined and defined independently of surface expressions (i.e. not by example), leads to the adoption of a method which is initially inductive: examining examples to identify and define structural relations, and then deductive: explicitly defining a limited set of structural elements and combining these elements in the analysis of particular texts.

8.3 Semantics of English Discourse

The semantic structural model which will be presented in the next chapter is similar in many respects to the semantic structures described by Simmons (1971). Like Simmon's model (and other current semantic models, e.g. Rummelhart, et al. 1972), the model incorporates semantic relations corresponding closely to the cases first described by Fillmore (1968, 1971). However, in attempting to formulate explicit definitions of case relations, it became necessary to depart from certain of Fillmore's cases. Certain of the relations of attribution defined in the model correspond to attributive relations described by Simmons. Quantifier relations correspond to generally familiar quantifiers used in linguistics and logic. The definitions of conditional relations in the present model (relations which connect propositions and make one proposition's validity conditional on the validity of another) were based on the papers of Rescher (1964) and Simon and Rescher (1966) which analyze contrafactual conditional relations and relations of causality respectively. Relations of equivalence, order, and proximity come from the algebra of relations and data theory (Coombs, 1964). The notion of a stochastic relation was adopted from psychological work on judgment and preference (cf. Tversky, 1969). Chafe's (1970) treatment of derivation was found to be valuable and many of his ideas concerning derivation were incorporated into the model. Leech's (1969) treatments of such topics as relative location, time, tense and aspect, and modality formed the basis for the treatment of these topics in the present model. Clark's (1972) discussion of types of negation formed the basis for the types of negation identified in the present model, and finally, Crother's (1971) discussion of the hierarchical and order properties of discourse was found to be particularly valuable. The influence of Crother's ideas concerning properties of discourse structures are apparent in much of what follows.

CHAPTER 9

GENERAL PRINCIPLES: GRAPH REPRESENTATION OF SEMANTIC AND LOGICAL STRUCTURE OF TEXTS

9.1 Introduction

A discourse consisting of one or more paragraphs has a number of properties which are of particular importance in constructing a semantic or logical representation of the set of sentences constituting the paragraph(s). The method for representing the semantic and logical structure which is adopted here takes certain of these properties as a starting point for the analysis of a text. In particular, eight "basic" semantic properties of texts consisting of one or more paragraphs are of interest. The basic elements of our semantic analysis correspond to these basic properties. The properties may be stated briefly as follows.

1. The sentences constituting a text are paraphrasable.
2. The semantic structure of a text is representable as a relational system.
3. The logical structure of a text is representable in terms of certain logical connectives defined on propositions represented in the semantic structure.
4. Ordered sequences of semantic relations representing a text have a unique dominance order.
5. A text usually possesses inexplicit tautologous semantic and logical relational structures.
6. The semantic structure of a text is hierarchical.
7. Representation of texts semantically requires certain logical transformations of semantic and logical relations.
8. Every text requires concatenated embedding of structural elements.

The first property refers to the fact that different sentences can be equivalent with respect to truth or falsity. In terms of logical implication, two sentences which are from a set of sentences which are paraphrases of one another, logically imply each other. From the point of view of semantic analysis, it is desirable to represent a set of sentences which constitute a "paraphrase set" in terms of a single semantic representation, i.e., it is desirable to regard the set of sentences as an equivalence class with respect to a given representation in the semantic structure defined on the set. A problem not considered here, is that of specifying rules of expression which are capable of generating grammatical sentences in the equivalence class of sentences for a given semantic structure.[1]

The second and third properties refer to aspects of semantic or logical representations of sentences. The basic constituent elements of the semantic structure are concepts, represented in the structure as words ("sememes") denoting the lexical meaning of the words, and certain directed binary relations connecting concept-pairs. The basic structural element in the semantic representation is an ordered triple or set relation $C_i R_j C_k$ consisting of a concept C_i, a connecting relation R_j, and a concept C_k. Word-concepts will be taken as primitives in the present analysis. The nature of lexical representations for concepts will not be considered and judgments of synonymy in scoring will be based on a standard dictionary citation and on context.[2,3] The semantic structure for a text consists of a network of set relations organized into a branching tree structure or directed graph (c.f., e.g., Harary, Norman, and Cartwright; 1965). Diagrammatically, the semantic structure consists of nodes (concepts) connected by directed lines (relations). This graphical network is called the semantic structure graph. Every ordered triple or set of ordered triples of the semantic structure defines a proposition which is either true or false.

The basic constituent of the logical structure is an ordered triple or logical relation $P_i L_j P_k$ consisting of a proposition P_i(represented structurally in the semantic structure graph), a connecting logical relation L_j, and a proposition P_k. Sets of logical relations can be arranged into directed graph structures with nodes representing propositions and connecting directed lines representing logical relations. This second type of graph is called (for want of a better name) the logical structure graph. Thus properties two and three indicate that associated with any text (and its set of paraphrases) are the two graph structures defined here--a graph representing the semantic structure and a graph representing the logical structure.

Property four indicates an important property of the semantic structure, namely that of dominance. Consider the sentence,

$$\begin{array}{cccc} C_2 & C_1 & C_3 & C_4 \\ \text{"Tall} & \text{men} & \text{read} & \text{books."} \end{array}$$

which is represented graphically as $C_1\ R_1\ C_2\ R_2\ C_3\ R_3\ C_4$ (definitions of types of relations will be presented later). Let $P_1 = [C_1\ R_1\ C_2]$, $P_2 = [C_1\ R_1\ C_2\ R_2\ C_3]$, and $P_3 = [C_1\ R_1\ C_2\ R_2\ C_3\ R_3\ C_4]$. Then P_3 implies P_2 which implies P_1 (i.e., "Tall men read books" implies "Tall men read," which implies that some men are tall). The dominance property of such a sequence of set relations is thus defined: any proposition given by a sequence of set relations up to a particular node implies the proposition given by the sequence up to the node immediately to the left of (superordinate to) that node.[4] A second interpretation of dominance may be made in terms of successively differentiated concept sets. In the above example, the graph may be interpreted as differentiating the set of men into those men who are tall, this set into those tall men who read, and those tall men who read into those tall men who read books. The dominance order may be interpreted as successive differentiations of the left superordinate concept set.[5] The dominance property described here characterizes any semantic structure which is an ordered sequence. Such order properties have not been a feature of most semantic descriptions of English. This ordering of the semantic relations representing a text is established principally by the hierarchical nature of the semantic structure graph (c.f., property 6) and by the directionality of case relations having causal significance.

Property five is extremely important for the semantic representation of texts (and for research on semantic memory and comprehension). Referred to here is the fact that while, for many texts there is an explicit semantic structure and an explicit logical structure (explicitly represented (coded) in the surface structure of the text), there is also a logically inferrable set of semantic relations and/or logical relations which is not explicitly represented in the surface structure of the text. Such structure is tautologous in that its derivation is strictly logical, involving only the explicit structure and lexical meaning of concept-words. Note, that in the analysis of (e.g.) causality, the notion of inferrable meaning may have to be expanded somewhat to include inferences based on semantic information outside of that represented in the text (e.g., some elementary physics in causal inference). Particularly likely to be omitted from the explicit structure are structures involving superordinate concepts.[6] Note that it is not in general possible to represent in the semantic and logical structure graphs all inferrable set relations and logical relations, especially since such relations can involve concepts or propositions not stated explicitly in the passage. This situation is a property of logical systems and might be termed "openness of meaning." The convention that will be chosen here is to represent structurally only those superordinate concepts necessary for the semantic structure graph to be hierarchical (a tree structure) with a single left superordinate concept-node. Property six refers to the occurrence of such an hierarchical structure for any text. A text for which this property does not hold would appear to have to be exceptionally disconnected with regard to subject matter, and will be considered to consist of multiple texts. Thus property six will be taken as a defining property of a text.

Property seven essentially qualifies properties two and three. Thus, while the semantic and logical structures of some texts can be represented in terms of certain relations connecting concept-pairs and certain logical connectives linking propositions, it may be necessary for a relation or logical connective belonging to the semantic and logical structure graphs (respectively) to be represented as altered ("qualified" or "operated upon") in some way. For example, since any proposition is either true or false, and since by convention propositions are only represented which are true, the truth value of a proposition may be altered, either by negation (reversal of truth value), by probabilistic qualification (rendered true with some probability), or by interrogation (truth-value interrogated). An example of an expression of negation is, of course, not; the probability operator may be expressed (e.g.) using the modal auxiliaries may and can. Other operators which have been found to be necessary are operations on temporality (e.g., tense), node deletion (e.g., participles, gerunds, truncated passives, some infinitives, and unclear antecedents of pronouns), and conditionality (rendering the truth value of a proposition conditional on other propositions being true).

The final property refers generally to the fact that for every proposition containing more than one relation, the left concept node for the second relation in the chain consists of a proposition defined by the preceding triple, the left concept node for the next relation in the branch consists of the proposition defined to that point in the chain, etc. To illustrate, return to the example "Tall men read books." C_1 R_1 C_2 represents "Some men are tall"; the next relation given by R_2 represents the statement that "Tall men read," the left "concept" node is the proposition (C_1 R_1 C_2) and the triple representing "Tall men read" should actually be represented as (C_1 R_1 C_2) R_2 C_3, etc. Thus the semantic structure graph for "Tall men read books" should be written (C_1 R_1 C_2) R_2 C_3) R_3 C_4. Since this property of concatenated embedding (set relations are embedded in set relations) always holds, it is not represented formally in the semantic structure but rather assumed. However, embeddings can occur which must be formally represented in order to be unambiguously defined.[7]

9.2 Semantic Structure

9.2.1 General considerations.

The semantic structure graph of a connected discourse represents in diagrammatic form the semantic content of statements which assert the occurrence of actions or states and specify further descriptive information pertaining to the asserted actions or states. Thus, a stated proposition is regarded as an assertion by the speaker communicating the information that certain events (actions) or states known to the speaker have, are, or will take place or obtain at some time, in some location, to some degree, etc. The semantic analysis of a speaker's sentence is based on a categorization of the asserted events or conditions surrounding the asserted event or state. The present semantic analysis follows that of Fillmore (1968) in treating the basic semantic structure of a sentence as consisting "of a verb and one or more noun phrases, each associated with the verb in a particular case relationship" (p. 21). This analysis differs with Fillmore's in its attribution of a particular dominance order (see the discussion of property four above) to the semantic elements of a sentence, and in its definitions of particular case relations.

Definitions of case relations utilized here are different from those of Fillmore (1968, 1971) for a number of reasons. First, it was considered unacceptable to have an "open case" containing all case relations not classifiable into the other defined cases. Since the purpose of the present analysis is to represent the "meaning" of a text, all cases must be explicitly defined; new cases ought to be defined as they become necessary. Second, the object case of

Fillmore's 1968 paper, taken in his narrow sense of things which are affected by the action or state identified by the verb, logically includes his dative, an animate being affected by the state or action of the verb, unless "thing" is read as inanimate. Third, rather than treat adjectives as stative verbs, it appears psychologically and semantically more reasonable to define specific attributive relations. For similar reasons, the attributive relations POSS and HASP were defined. In the present model, the instrument case of Fillmore (1968) has been narrowed to include only inanimate nouns directly causing the action of the verb, since the manner class of adverbial modifiers would appear to be included within Fillmore's instrument case. In terms of the case relations hypothesized by Fillmore in his later (1971) paper, there is a rough equivalence between the source, locative, and temporal cases; and between Fillmore's "Experiencer" and "Goal," and the dative and factitive cases of the present analysis, respectively. Fillmore's "Agent" and "Instrument" cases are different from those of the present analysis; the differences will be discussed at length below. Fillmore's object case remains "open" in his later paper; the present analysis defines the object case specifically and then defines two additional cases "theme" and "goal" (the latter not to be identified with Fillmore's goal case which is called factitive here). The logical structure and transformations of either semantic or logical relations are not considered in Fillmore's analysis.

A list of the designated case relations which may occur in the semantic structure graph is presented in Table 9.1 and a summary of the definitions of certain case relations to action and state verbs is given in Figure 9.1. Semantic relations are classified as those involving attribution, quantification of concept-sets, relations to action verbs, relations to state verbs, and certain other relations pertaining to action or state verbs including adverbial modifiers specifying location or spatial position (locative), time or temporal interval (temporal), degree of action or state (degree), and the manner in which an action took place or a state obtained (manner); and the relations goal and theme.

9.2.2 Attributive relations. The attributive relations are broken down into (1) those paraphrasable using the verb IS or IS A and (2) those paraphrasable using HAS. Of the attributive relations pertaining to IS or IS A constructions, are relations specifying an extensive (quantitative) property of a concept (EXT) such as "tall boys" or "the boy is ten years old," and relations specifying either categorical properties of a concept-set (ordered classes) (CAT 1) or a classification of a concept by assigning it to a particular class (CAT 2). Examples of these two sorts of CAT relation are "bright children" (used in a categorical sense) and "the islanders consisted of farmers and ranchers." An extensive property is treated as categorical only if its usage is clearly categorical as in "the bright children were fewer in number than the dull children." The general form of the relation EXT is

$$A \xrightarrow{\text{EXT } i} B,$$

Where A is an object or being, B designates an attribute scale or an

Table 9.1

List of Designated Relations in Semantic Structure Graph

I. Attribution: IS, ISA

IS	extensive property	$\xrightarrow{\text{EXT } i}$
IS A	ordered classes (CAT 1)	$\xrightarrow{\text{CAT 1}}$
	Classification (CAT 2)	$\xrightarrow{\text{CAT 2}}$
IS	identity	$\xleftrightarrow{\text{IDENT}}$
IS + prep.	location	$\xrightarrow[(j)]{\text{LOC } i}$
IS + prep.	time	$\xrightarrow{\text{TEM } i}$

II. Attribution: HAS

HAS part	object property	$\xrightarrow{\text{HASP}}$
HAS	possession	$\xrightarrow{\text{POSS}}$

III. Quantification of Noun Concepts

ALL	universal quantifier	
NUMBER	count nouns	$\xrightarrow{\text{NUM } i}$
TOKEN	particular instance	$\xrightarrow{\text{TOK}}$
DEFINITE	definite referent	$\xrightarrow{\text{DEF}}$
ϕ	negative quantifier	$\xrightarrow{\phi}$
EACH	for all	$\xrightarrow{\text{EACH}}$
$\exists$	existential quantifier	$\xrightarrow{\exists}$

IV. Case Relations to Action Verbs

AGENTIVE	$\xrightarrow{\text{AGT}}$
DATIVE	$\xrightarrow{\text{DAT 1}}$
INSTRUMENTAL	$\xrightarrow{\text{INST}}$
OBJECTIVE	$\xrightarrow{\text{OBJ 1}}$
SOURCE	$\xrightarrow{\text{SOURCE}}$
FACTITIVE	$\xrightarrow{\text{FAC}}$

V. Case Relations to State Verbs

DATIVE	$\xrightarrow{\text{DAT 2}}$
OBJECTIVE	$\xrightarrow{\text{OBJ 2}}$

Table 9.1 (cont.)

VI. Adverbial Modifiers

LOCATIVE		$\xrightarrow[(j)]{\text{LOC } i}$
TEMPORAL		$\xrightarrow{\text{TEM } i}$
DEGREE		$\xrightarrow{\text{DEG } i}$
MANNER	ordered classes	$\xrightarrow{\text{MAN } 1}$
	classification	$\xrightarrow{\text{MAN } 2}$

VII. Further Specification of an Action or State

GOAL	$\xrightarrow{\text{GOAL}}$
THEME	$\xrightarrow{\text{THEME}}$

Figure 9.1

Case relations to action and state verbs.

B: VERB

		action	state
A: NOUN	animate	AGT	CAU
	inanimate	INST	CAU

A is the immediate (proximal) cause of B.

B: NOUN

		animate	inanimate	
A: VERB	action	DAT 1	OBJ 1	(1)
	action	FAC	FAC	(2)
	state	DAT 2	OBJ 2	(1)
	state	CAU	CAU	(2)

(1) B is affected directly (proximally) by A.

(2) B results directly (proximally) from A.

open interval on an attribute scale, and the relation EXT i assigns property B to A. If i = 1, then EXT 1 assigns an attribute scale to A but does nothing more than designate the attribute B as applicable to A. If i = 2, then EXT 2 maps A onto an interval on the attribute scale but does not specify a point value for A (e.g., "John is tall"). In this latter case (EXT 2), the attribute scale is denoted by a name designating a direction on the scale followed by a minus sign if the direction is to be construed as negative. Thus "John is short" is represented:

$$\text{John} \xrightarrow{\text{EXT 2}} \text{short } (-),$$

where short is construed as the negative direction on the scale of height. Point values of the attribute are specified by the relation DEGREE (e.g., "John is six feet tall"). An interval assigned by the relation EXT 2 is open in that it does not have specified endpoints. A closed interval may be specified using the relation DEGREE to specify point values for the end-points of the interval (e.g., "John is between five and six feet tall"). In EXT 2, an adjective may function to assign to each value on the attribute scale a probability that each proposition which specifies a particular value for the attribute is true, i.e., the relation EXT 2 may be thought of as inducing a probability distribution or cumulative probability distribution on an attribute scale. In scaling theory, such distributions have been called discriminal processes (c.f., Bock and Jones, 1968).

Attributive relations involving HAS are of two types, (1) relations denoting an object property of a concept such as a part of the body (e.g., "John's hand") (HASP for HAS PART), and (2) relations indicating possession of something representable as a noun (POSS) (e.g., "John's ball"). HASP and POSS may be distinguished by the following test: if the proposition involving HAS is necessarily true, the relation is HASP (inalienable possession); otherwise it is POSS. Confusion of EXT and POSS can occur with such nominalized concepts as "intelligent" and "intelligence"; generally, the sentences "John is intelligent" and"John possesses intelligence" will not be taken as paraphrases of each other. The first sentence will be taken to mean "John is intelligent to some (unspecified) degree" and the second as "John possesses the faculty (nominalized attribute) of intelligence." The sentences "John possesses a fair degree of intelligence" and "John is fairly intelligent" will not be taken as synonymous, although the difference in meaning is admittedly fine and likely to depend on context. In instances such as this, the strategy adopted in deciding on a semantic representation was to "follow" the surface structure of the sentence. Confusion of HASP and CAT may also occur. In general, HASP will be used when in

$$A \xrightarrow{\text{HASP}} B,$$

A is a single entity or collection of entities each of which is a system of interrelated parts which are not homogeneous (i.e., do not possess a large number of semantic features in common) and B is an entity or set of entities as in "the antelope has antlers"; CAT will be used when in,

$$A \xrightarrow{\text{CAT}} B,$$

A is a collective noun: a collection of elements which are not necessarily an interrelated system, the elements of which all possess a large number of semantic features in common, and which possess a small number of features which differentiate them (a homogeneous set): and B is a category (classification) or categorical property.

9.2.3 Derived attribution. There are three common types of "attributive" relations which are basically different from the attributive relations just described even though they may be expressed using the verb IS. The nature of this difference may be seen by considering the following sets of sentences:

1a The window is broken
1b The window has been broken.
1c Someone has broken the window.
2a This cereal is edible.
2b This cereal can be eaten.
2c One can eat this cereal.
3a John is sad.
3b John feels sad.

The characteristic of sentences 1a, 2a, and 3a which renders them different from such sentences as "The window is large," "The cereal is soggy," and "John is tall" is their derivative nature: 1a may be considered to be derived from 1c (since "broken" involves nothing more than the result of the action "break"), 2a is derived from 2c since "edible" specifies only that the cereal can be the object of the action "eat," and 3a is derived from 3b since "sad" characterizes an understood stative verb "feel." The attributive surface forms represent convenient abbreviations of the underlying propositions from which they are derived. Attributives corresponding to expressions such as these will be referred to as derived attributes and will be represented semantically in terms of the semantic structures (involving active or stative verbs) from which they are derived. Three types of derived attribution correspond respectively to these three examples: (1) resultive attribution: expressing as an attribute the result of an action (cf. Chafe, 1970, pp. 124-125), (2) deactivative attribution: expressing as an attribute the fact that an object can serve as the object of an action (cf. Chafe, 1970, pp. 131-132), and (3) experiential attribution: expressing as an attribute an experienced state. The structural representation of each type of derived attribute requires the use of semantic relations defined in later sections. However, for subsequent reference the general form for propositions indicating derived attribution will be presented here.

1. resultive attribution: $\text{action} \xrightarrow{\text{FAC}} [\text{A} \xrightarrow{\text{CAT 2}} \text{X}]$
2. deactivative attribution: $\text{X} \xrightarrow[\text{(can)}]{\text{QUAL(AGT)}} \underline{\text{action}} \xrightarrow{\text{OBJ}} \text{A}$
3. experiential attribution: $\text{A} \xrightarrow{\text{DAT 2}} \underline{\text{feel}} \xrightarrow{\text{MAN 2}} \text{B}$

In the above expressions, A and B refer to specified concepts and X refers either to a "dummy concept" which is completely defined by the context (e.g., "broken") or to any unspecified concept.

9.2.4 Quantifiers. Quantification of noun concepts is denoted in two ways in the semantic structure graph; either by indicating the nature of the quantification in parentheses after the noun (if superordinate "levels" of quantification are not represented) or by indicating the quantifier as a relation (if the superordinate concept is represented in the semantic structure). The levels of quantification represented include (starting with the most general set and proceeding to the smallest concept set, i.e., from superordinate to subordinate); the universally quantified set (all instances of a concept), e.g., "people" or "all people"; a number of instances selected from the general class (NUM), e.g., "some people"; a particular instance from a class (TOK), e.g., "a person"; a particular instance from a class which has a definite reference to another concept (DEF), e.g., "the person over there"; and the empty class (negatively quantified set) ($\emptyset$), e.g., "no people." Also represented is the particular instance selected as representative of a concept class (the logical "for all," EACH), e.g., "each of the boys has a pencil; and the existential quantifier, "there are boys who play ball." The relation NUM may be further subdivided into two relations: one in which NUM assigns a positive integral value to the number of instances from the general class (NUM 1, e.g., "ten boys") and one in which the relation does not precisely specify the number of instances from the general class (NUM 2). In the relation NUM 2, the relation may either specify the count to be in an open interval (e.g., "some boys," "many boys") or in a closed interval (e.g., "between 10 and 15 boys"). Open and closed intervals are denoted in the same manner as for the relation DEG 2(to be discussed below). The relation NUM 2 may also function in a manner parallel to the extensive relation EXT 2: it may be thought of as inducing a discrete probability distribution on the positive integers.

9.2.5 Case relations. Case relations to action verbs (which by definition represent a change of state) and relations to stative verbs are summarized in Figure 9.1. Consider first the cases in which, in the relation A R B, A is anything representable as a noun and B is a verb. If A is animate, B is an action verb and the relation is "A is the immediate (proximal) cause of the change of state represented by B," the relation is labelled "agent" (AGT): if it is inanimate, B is an action verb, and the relation is "A is the immediate cause of the change of state represented by B," the relation is that of instrumentality (INST). If B is a state verb, then B does not represent a change of state, and thus does not have a proximal cause. The relation CAU is used to represent distal causes including causes of states in which the action leading to the state has not been specified (e.g., "The exam made (CAU) me feel terrible"). If A is the agent of an action verb B, and A also is directly affected by the action of B (i.e., the verb is reflexive), then A will be defined as both dative (DAT 1) and agent (ACT) since A in this case shares AGT and DAT 1 relations to the verb. Note that under the present definition of AGT and INST, if one considers a causal chain leading to an action, the instrument is that inanimate object which is asserted by the speaker to be proximally (immediately) involved in the action of the verb; the agent is that animate object most proximally involved in the action of the verb. The directionality of the relations AGT, INST, and DAT (reflexive) is given by their causal significance to the verb. In general, if the agent precedes the verb, then other noun phrases must follow the verb since they either differentiate the action caused by the agent or represent effects of the verb. If there is no agent, then the instrument adopts the role of agent in the order.

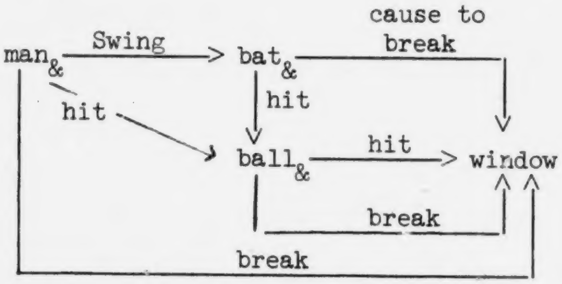
Since it has been proposed by others that selection restrictions involving animateness ought not to occur in the definition of case categories (Fillmore, 1971), some reason should be offered for attaching the feature /+animateness/ to nouns functioning as agents and /-animateness/ to nouns functioning as instruments. The sentence (a) "John made the ball break the window" may be paraphrased "John broke the window with the ball," the instrument "ball" determining the preposition "with." But the sentence (b) "John made Judy break the window" may not be paraphrased "John broke the window with Judy," unless John used Judy as a physical object to break the window (or if they broke the window together). The critical feature in the above distinction is the animateness of Judy. Applying our definitions of AGT and INST, in sentence (a) the ball will be taken as the instrument and John as the agent of the verb "break"; in sentence (b) Judy will be regarded as agent of the verb "break," and the relation of John to the verb "break" must be expressed using the causal connective CAU (defined below). A syntactic reason for treating the agent as "the most proximal animate cause" and other animate beings causally involved in the action as connected to the action by the relation CAU in the logical structure graph is provided by the following example. Given sentence (b) we may say "The window was broken by Judy," the agent Judy determining the preposition "by," but we may not say "The window was broken by John." We must say "John caused the window to break."

Some additional remarks on the causal nature of agency and instrumentality are necessary, since causality is defined as a logical connective in the logical structure graph, and AGT and INST are defined in the semantic structure but also involve causal relationships to a verb. The problem is how may we distinguish between agency and instrumentality, on the one hand, and causal connectives on the other; i.e., should the sentences (a) "John caused the window to break" and (b) "The hammer caused the window to break" be considered as paraphrases respectively of (c) "John broke the window" and (d) "The hammer broke the window"? In the present analysis, the sentence pairs (a), (c), and (b), (d) will not be taken to be paraphrases since (a) and (b) appear to contain a possible ambiguity which sentences (c) and (d) do not: sentences (a) and (b) may be used to express either (1) a chain of causal events leading from John or the hammer to the window, or (2) the agency of John or instrumentality of the hammer.

It remains to indicate why the relations AGT and INST are represented in the semantic structure while CAU (the causal connective) is represented in the logical structure. This distinction seems appropriate for the following reason. Recall that the semantic structure graph represents statements which assert the occurrence of actions or states and specify further descriptive information pertaining to the asserted actions or states. The logical structure represents relations defined on propositions taken from the semantic structure which may place constraints on the propositions of the semantic structure. Often the semantic structure of a discourse is incomplete in its description of the causal relationships involved in asserted actions or states; in these instances causal relations in the logical structure are required to completely specify the network of causal relationships. As an example, consider the following sentences:

1a The man hit the ball and the window broke.
1b The man hit the ball causing the window to break.
2a The man hit the ball and broke the window.
2b The man hit the ball and thus broke the window.
3a The man hit the ball and the ball broke the window.
3b The man hit the ball, thus causing the ball to break the window.

Sentences 1 to 3 present increasing information about the relationships among the man, the ball, and the window. For each numbered example, sentence (b) employs a causal connective to indicate a causal relation not given by sentence (a). Suppose, following the example cited by Fillmore (1971), that the causal system to be expressed involves four objects, a man, a bat, a ball, and a window, and the actions swing, hit, and break.[8] The event to be described may be represented diagrammatically as follows:



One way in which this chain of events might be expressed is as follows: "The man swung the bat, the bat hit the ball, the ball hit the window and broke it." A complete description of the causal system above requires insertion of the causal connective "thus" (or "thus causing"): "The man swung the bat, thus the bat hit the ball, and thus the ball hit the window and broke it." As Fillmore pointed out, we can say "The man hit the ball" and "The man broke the window," but we cannot say "The bat broke the window"; the latter causal relation requires the logical connective, as in "The bat caused the window to break." Thus, it appears as if the linguistic role of logical connectives includes the expression of causal relationships which are inexpressible (for various reasons) by other means. It also appear that such connectives are likely to be deleted in everyday language, thus requiring the comprehender to generate (infer) the deleted causal or other conditional relations for himself.

Now consider the cases summarized in the lower part of Figure 9.1 in which in the relation A R B, A is a verb (the action being the result of an agent, an instrument, or (for an action or state) the result of some causal sequence of events not necessarily specified), B is anything representable as a noun, and the relation R is "B is affected directly (proximally) by A." If A is an action verb, B is animate, and the asserted relation is "B is affected directly by A," then the relation is defined as dative (DAT 1) (beneficiary or recipient of an action). If A is a stative verb, B is animate, and the relation is "B is affected directly by A," then the relation is designated DAT 2 (roughly equivalent to Fillmore's (1971) "Experiencer" case). Thus, dative case relations may be separately defined corresponding to action verbs (DAT 1) or state verbs (DAT 2). They may be further classified on the basis of particular effects of the verb on B (the change which A induces in B for actions and the type of state for stative verbs). Particular changes in B which may be identified are changes in attribution: EXT (e.g., "He made John (DAT) angry"), POSS (e.g., "He gave the pen to John"), HASP (e.g., "He removed the tumor from John"), LOC (e.g., "He pushed John into the lake"), and TEM; and actions (e.g., "He persuaded John to go"). Types of states may be classified on the basis of whether the stative verb takes the relation THEME (e.g., verbs such as "know," "believe"), the relation GOAL (e.g., "want," "desire"), or the adverbial relation MANNER (e.g., "feel" as in "feel cold"). (The relations THEME, GOAL, and adverbial relations are defined subsequently.) Dative relations may either govern the preposition "to" (if the effect is to induce possession) or the case marker may be absent. Case categories such as DAT may be reflected in word order (Fillmore, 1968).

If A is an action or state, B is inanimate, and relation is "B is affected directly by A," then the relation is objective (OBJ). As with the dative, if A is an active verb the relation is designated OBJ 1 and indicates that a change in the state of B occurred resulting from the action A; if A is stative, the relation is designated OBJ 2. Particular changes in the object affected include changes in attributive relations and in actions involving B as instrument or cause. The distinction between DAT and OBJ on the basis of the feature /+animateness/ is made for the following reason. Since a noun in a dative relation to a verb may also simultaneously be agent to the same verb (i.e., in the reflexive case), and since animateness is a defining feature of agency, then animateness ought to be a defining feature of DAT and critical feature distinguishing DAT from OBJ nouns which necessarily cannot act as agents.

The remaining relation in the semantic structure which is identified in Figure 9.1 is the factitive (FAC) relation defined when B, anything representable as a noun, "results directly (proximally) from" an action A. As with DAT and OBJ, different categories of FAC may be distinguished on the basis of the particular changes resulting from the action of the verb. The case relations DAT, OBJ, and FAC are illustrated by the sentences

> He gave the pen to John.
> He persuaded John to go.
> He pushed John into the lake.
> Soren made me a toy house.

which may be diagrammed as follows

$$\begin{tikzcd}
\text{He} \arrow[r, "\text{AGT}"] & \text{gave} \arrow[r, "\text{DAT 1}"] \arrow[dr, "\text{OBJ 1}"'] & \text{John} \\
 & & \text{pen}
\end{tikzcd}$$

$$\begin{tikzcd}
\text{He} \arrow[r, "\text{AGT}"] & \text{persuaded} \arrow[r, "\text{DAT 1}"] \arrow[dr, "\text{FAC}"'] & \text{John} & \\
 & & {\text{[John}} \arrow[r, "\text{AGT}"] & {\text{go]}}
\end{tikzcd}$$

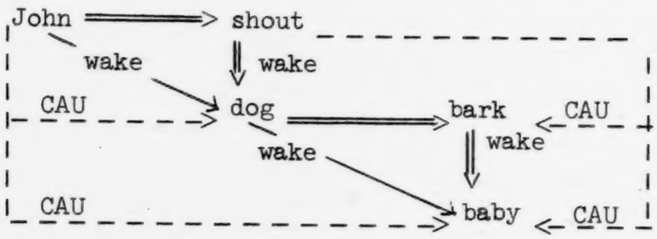
$$\begin{tikzcd}
\text{He} \arrow[r, "\text{AGT}"] & \text{pushed} \arrow[r, "\text{DAT 1}"] \arrow[dr, "\text{FAC}"'] & \text{John} & \\
 & & \text{John} \arrow[r, "\text{LOC}"] & {\text{lake (def)]}}
\end{tikzcd}$$

$$\begin{tikzcd}
\text{Soren} \arrow[r, "\text{AGT}"] & \text{made} \arrow[r, "\text{DAT 1}"] \arrow[dr, "\text{FAC}"'] & \text{me} & \\
 & & {\text{[house}} \arrow[r, "\text{CAT 2}"] & {\text{toy]}}
\end{tikzcd}$$

As in the case of agency and instrumentality, further remarks are required on distinctions between the relations DAT 1, OBJ and FAC which have causal significance, and the logical connective CAU represented in the logical structure. The problem involves whether or not the following sentence pairs should be regarded as paraphrases of one another:

1a John's anger frightened me.
1b As a result of John's anger, I was afraid.
2a He persuaded John to go.
2b As a result of his persuasion, John went.
3a The bad news annoyed me.
3b The bad news caused me to be annoyed.

In the present analysis these sentence pairs will not be regarded as paraphrases for the same reason indicated in the discussion of AGT and INST, viz., the second sentence of each pair is ambiguous with regard to the possible occurrence of intervening events. That the definitions of DAT 1, OBJ and FAC ought to be restricted to nouns involved proximally in the causal sequence, and that nouns indirectly "affected by" or "resulting from" an action or state ought to be represented in the logical structure (using CAU) may be seen by considering the following chain of events represented diagrammatically):

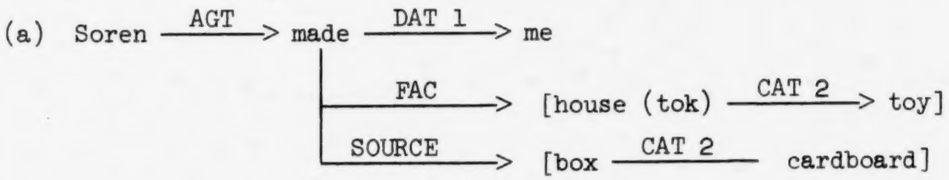


This chain of events might be expressed by saying, "John shouted, the shout woke the dog, the dog barked, and the bark woke the baby" (the double lines in the diagram). Now note that you can say "The dog woke the baby" and "John woke the dog" but you cannot say "John woke the baby." You can say "John caused the baby to wake." The dotted lines in the diagram represent causal relations which may only be expressed using the logical connective CAU. Thus, as in the case of agency and instrumentality, it appears as if in English the role of causal connectives is in the expression of indirect causal relationships which may not be represented directly in the semantic structure. A similar argument can be made for considering FAC to involve the proximal result of an action or state.

One remaining semantic relation designated in Table 9.1 as a case relation to an action verb remains to be defined to handle such sentences as:

a. Soren made me a toy house from a cardboard box. 9
b. He walked from the top of the hill to the cemetery gate.

In these examples, "a cardboard box" and "the top of the hill" represent prior states of the object or being affected by or resulting from the action of the verb and "a toy house" and "the cemetery gate" represent states resulting from the action of the verb. Thus, the relation SOURCE is defined as follows. If A is an action verb, B is anything representable as noun, and the relation A R B represents "B obtains immediately (proximally) prior to A," then the relation R is that of SOURCE. Note that SOURCE and FAC are symmetric: SOURCE represents a prior state, FAC represents a resulting state, and both states are spatially and temporally proximal to the action of the verb. Both SOURCE and FAC relations may be classified with respect to the nature of the prior or resulting state or action; the major categories appear to be prior states or outcomes involving: verbs of transformation which change a prior concept into a new one (e.g., sentence (a) above); verbs inducing a change in attribution (e.g., EXT: "He painted the red house green," POSS: "The thief removed the man's money and left him penniless," LOC: Sentence (b) above, TEM: "He walked from noon until sundown"9); and verbs inducing actions (e.g., "The mother made the misbehaving child go to his room"). Following Fillmore (1971, p. 41), it may be that sources and factitives occurring in relation to a single verb must be homogeneous, r.e., category of prior or resulting action or state (including homogeneity with respect to particular attribute dimensions). To illustrate how sentences such as (a) and (b) are represented graphically, diagrammatic representations of (a) and (b) follow:



$$\text{(b) He} \xrightarrow{\text{DAT 1}} \text{walked} \left[\begin{array}{l} \xrightarrow{\text{SOURCE}} [\text{He} \xrightarrow{\text{LOC}} [\text{hill (def)} \xrightarrow{\text{HASP}} \text{top}]] \\ \\ \xrightarrow{\text{FAC}} [\text{He} \xrightarrow{\text{LOC}} [\text{cemetery} \xrightarrow{\text{HASP}} \text{gate}]] \end{array}\right.$$

Two additional classes of relations in the semantic structure remain to be discussed: the adverbial modifiers specifying location, time, degree, and manner; and two relations which further specify an action or state: GOAL and THEME. Since a discussion of adverbials of location, time, and degree must inevitably include consideration of relative item, relative position, and relative degree, and since these relative adverbials involve connectives defined in the logical structure (in particular order, proximity, and certain algebraic relations), this section will conclude with definitions of the relations of time, location, and degree. Relative adverbials of location, time, and degree will be discussed in the next section. Analysis of adverbial relations of location and time are based in part on Leech's (1969) discussions of locative and temporal expressions.

The relations GOAL and THEME are necessary to represent certain case relations to verbs which do not represent instances of any of the case relations previously defined. The relation GOAL is defined as follows: If A is an action (or state), B is a future state (or future-in-the-past if the verb's action occurred in the past), and the relation is "B is the immediate (proximal) future state towards which the verb's action is directed (or to which the state refers)", then the relation is GOAL. The relation GOAL appears to involve the actions of animate beings: actions which are construed by the speaker to be voluntary. The following example illustrates why (outside of considerations of symmetry with SOURCE and FAC) the relation GOAL is restricted to proximal states. Suppose John is studying because he wants to pass an exam, that he wants to pass the course in which the exam is given, and that he must pass the exam in order to pass the course. This example contains two goals, a superordinate goal (passing the course) and a subgoal (passing the exam). One can say "John is studying to pass the exam" and "John is studying to pass the course," but "John is studying to pass the exam to pass the course" is not acceptable without marking the superordinate status of the second goal. One can say "John is studying to pass the exam, to pass the course" or possibly "John is studying to pass the exam and thus to pass the course." It also appears that by "strengthening" the preposition "to," an acceptable sentence results, e.g., "John is studying to pass the exam in order to pass the course." Rank-equivalent goals may also occur as in the sentence "John is studying to pass the exam and the course." While there is some degree of symmetry of GOAL (future state) with SOURCE (prior state) and FACTITIVE (resulting state), it appears as if the symmetry is incomplete since a sentence may include more than one goal while a sentence may refer to only one (proximal) prior state and only one (proximal) resulting state.

The relation THEME is necessary for representing semantic relations involving certain verbs in which a state or a state resulting from the action of a verb has (or is understood by the speaker to have) symbolic significance (e.g., the stative verbs "know," "believe," "understand"; the action verbs "write," "dream," "think," "imagine"). In the relation A R B, let A be an action or state and let B be anything representable by a noun. Then the relation THEME is defined as follows: B represents the (symbolic) content or a part of the content of a symbolic state or of the factitive symbolic state resulting from the action of A. The relation THEME determines the preposition "about." The following examples illustrate why in the case of actions THEME is defined as denoting the content of the factitive state resulting from an action:

1a He wrote a book about Chinese history.
1b He wrote about Chinese history.
2a He studied a book about Chinese history.
* 2b He studied about Chinese history.
2c He studied Chinese history.

In sentence 2a "Chinese history" is the theme of the book, but "book" is not the result of the verb "study"; hence 2b is not acceptable. Sentence 2c, in which "Chinese history" is the object of the verb "study," is acceptable.

9.2.6 Types of derived verbs. A semantic analysis of sentences containing action verbs has been presented which involves specifying (1) the causal agent and (or) instrument, (2) the object (animate or inanimate) affected by the action indicated by the verb, (3) the state which existed immediately prior to the change induced by the action, and (4) the state resulting from the action of the verb. The case grammar analysis of such sentences is verb centered in the sense that the event is represented semantically in terms of a verb and various concepts in case relations to the verb. Certain situations may occur involving action verbs expressing change of state and/or agency or instrumentality in which the action is derived from a "stative proposition," i.e., an attributive proposition or a proposition involving a stative verb. Consider the following sentences:

1a The road is wide.
2a The road widened.
2b The road became wide.
3a The workmen widened the road.
3b The workmen made the road become wide.
4a She married him.
4b She became his wife.
5a The movie saddened him.
5b The movie made him become sad.

The active verbs in sentences 2a and 3a are derived from the attribute of sentence 1 in the following ways. Sentence 2a differs from 1 in that 2a asserts not only that a state obtains but in addition asserts that a change of state has occurred. The paraphrases of 2b makes explicit the derived nature of "widened" in this example. In such situations the verb "become" contains no meaning other than the fact that a change of state has occurred. The structural relations OBJ 1, DAT 1, SOURCE. and FAC , and the concepts connected to the verb "become" by these relations completely specify the meaning, i.e., the verb "become" acts as a sort of "dummy argument" because it contains no meaning which is not already given by the structure into which it is embedded. Sentences such as 2a, 2b, 4a, 4b expressing simple change, possibly by means of derived inchoative verbs such as "widen" (cf. Chafe, 1970, pp. 122-124), are represented structurally by the following general forms (the first for changes of attribution and the second for changes represented by stative verbs, viz. experiences):

1.
$$\begin{tikzcd} & & \lbrack X \arrow[r, "R"] & Y_1] \\ X \arrow[r, "\substack{\text{OBJ 1}\\ \text{or DAT 1}}"] & \underline{\text{become}} \arrow[ur, "\text{SOURCE}"] \arrow[dr, "\text{FAC}"'] & & \\ & & \lbrack X \arrow[r, "R"] & Y_2] \end{tikzcd}$$

2.
$$\begin{tikzcd} & & \lbrack X \arrow[r, "\text{DAT 2}"] & \text{verb} \arrow[r, "R"] & Y_1] \\ X \arrow[r, "\text{DAT 1}"] & \underline{\text{become}} \arrow[ur, "\text{SOURCE}"] \arrow[dr, "\text{FAC}"'] & & & \\ & & \lbrack X \arrow[r, "\text{DAT 2}"] & \text{verb} \arrow[r, "R"] & Y_2] \end{tikzcd}$$

In general, if a surface sentence contains a derived verb other than "become," it should be represented using "become" only if one of the above general forms completely represents the meaning and hence contains no concepts not expressed in the surface sentence.

Sentence 3a differs from sentence 1 in that 3a asserts not only that a state obtains but in addition that a change of state has occurred as a result of an (unspecified) action of the agent "workmen." The paraphrase 3b makes explicit the derived nature of the verb "widened" in this example. As in sentences expressing simple change, structural relations (viz. AGT, INST, OBJ 1, DAT 1, SOURCE, and FAC) and concepts connected to the verbs "make" and "become" completely specify the meaning and the verbs "make" and "become act as "dummy arguments." Derived verbs such as "widened" in 3a may be either agentive + inchoative, or instrumentive + inchoative (e.g. sentences 5a and 5b). Note that the term "causitive" is not used (cf. Chafe, 1970, p. 128) because in sentences such as 3b and 5b the cause is proximal, e.g., the sentence "The workmen caused the road to become wide" is ambiguous re. the possibility that the workmen were only indirectly responsible for the change. Sentences expressing simple agency + simple change are represented by the following general forms:

3. $X \xrightarrow{\substack{\text{AGT}\\ \text{or INST}}} \underline{\text{make}} \xrightarrow{\text{FAC}} [Y \xrightarrow{\substack{\text{OBJ 1}\\ \text{or DAT 1}}} \underline{\text{become}} \xrightarrow{\text{FAC}} [Y \xrightarrow{R} Z]]$

4. $X \xrightarrow{\substack{\text{AGT}\\ \text{or INST}}} \underline{\text{make}} \xrightarrow{\text{FAC}} [Y \xrightarrow{\text{DAT 1}} \underline{\text{become}} \xrightarrow{\text{DAT 2}} [Y \xrightarrow{\text{DAT 2}} \text{verb} \xrightarrow{\text{R}} Z]]$

9.2.7 Adverbial relations. Relations of location have the general form

$$A \xrightarrow[(j)]{\text{LOC } i} B$$

where A is anything representable by a noun or verb, B is a spatial location, and the relation LOC assigns location B to the object or event A. The relation LOC involves the parameters i and j, where $i = 1$ or 2 and $j = 0, \ldots, 3$, and these parameters specify each member of the family of relations called locatives. If the parameter $i = 1$, then the relation assigns a point in space to the object or event A; if $i = 2$, then the relation maps the object or event A onto a region in space, but does not specify a point location for A. The assigned region may be either open (with unspecified boundaries as in the case of the relation EXT 2) or closed (with specified boundaries). The parameter j is equivalent in value to the dimensionality of the relevant space (relevant to establishing the location of the object or event A). The relevant dimensionality may not be equivalent to that of the physical system to which reference is made by the speaker; it will often be less depending on the presuppositions of the speaker. For example, certain kinds of relative location (e.g., locatives of direction and orientation) involve the presupposition of a fixed one-dimensional reference axis in two or three dimensional space. Relative locative expressions may also involve a point of orientation which may correspond to the speaker's location (e.g., locatives of orientation). Some examples of relations of simple location are given in the following list:

1. point:

$A \xrightarrow[(0)]{\text{LOC 1}} B$	at the door
$A \xrightarrow[(2)]{\text{LOC 1}} B$	at the center of the lake
$A \xrightarrow[(3)]{\text{LOC 1}} B$	at the top of the mountain

2. open region:

$A \xrightarrow[(1)]{\text{LOC 2}} B$	on the road, on the border
$A \xrightarrow[(2)]{\text{LOC 2}} B$	in the field, on the map
$A \xrightarrow[(3)]{\text{LOC 2}} B$	in the box

3. closed region:

$A \xrightarrow[(1)]{\text{LOC 2}} \begin{bmatrix} B_1\ (\text{LOC 1}) \\ B_2\ (\text{LOC 1}) \end{bmatrix}$	between Washington and Philadelphia

The above relations of simple location, in combination with certain algebraic relations and relations of order, equivalence, and proximity, permit one to represent semantically a great many expressions of relative location. Relations of relative location will be discussed in the next section.

Temporal information concerning objects or events in a discourse may be represented either by means of tense and aspect operators, or by means of temporal expressions (for both objects and events). Tense and aspect operators specify relative time (relative to the factual present) and temporal expressions, semantically represented by structures containing the temporal relation

$$A \xrightarrow{\text{TEM } i} B,$$

specify either simple time (assignment of a point or interval on the time scale to an object or event) or relative time (relative to a point of orientation which may or may not coincide with the factual present). The relation TEM is defined as follows: A is an object or event, B is a moment or interval of time, and the relation

$$A \xrightarrow{\text{TEM } i} B$$

assigns the moment or interval of time B to A. If i = 1, then the relation

$$A \xrightarrow{\text{TEM 1}} B$$

maps A onto a point on the time scale (e.g., "at two o'clock"); if i = 2, then the relation

$$A \xrightarrow{\text{TEM 2}} B$$

maps A onto an interval which may be either open (unspecified duration, e.g., "on Monday morning," "in the spring semester," "in the future") or closed (specified duration, e.g., "between five and six o'clock," "for three hours"). In the latter closed temporal relations, either the end points of the time interval are represented:

$$A \xrightarrow{\text{TEM 2}} \begin{bmatrix} t_1 & (\text{TEM 1}) \\ t_2 & (\text{TEM 1}) \end{bmatrix}$$

(e.g., t_1 = 5 o'clock, t_2 = 6 o'clock), or the length of the time interval is indicated:

$$A \xrightarrow{\text{TEM 2}} T$$

(e.g., T = 3 hours). Representation of relative times not involving tense such as "before" and "after," measured intervals, relative duration and still more complicated structures require certain algebraic relations and order and equivalence relations.

Adverbials of degree are represented in the semantic structure by means of the relation

$$A \xrightarrow{\text{DEG } i} B,$$

where A is an event, extensive attribute, extensive manner, or degree, B is a point value or an interval on a magnitude scale (of degree), and the relation DEG i assigns degree B to event, attribute, manner, or degree A. If i = 1, the relation DEG 1 specifies B to be a point value in some unit of measure which identifies the scale (e.g., "John is six feet tall"); if i = 2, the relation DEG 2 assigns to A a degree within either an open interval (e.g., the intensifier "very" as in "John is very tall," "John is average height," "John types very rapidly") or a closed interval (e.g., "John is between five and six feet tall," "John types between fifty and sixty words per minute"). As in the case of the relation EXT 2, the degree scale is denoted by a name designating a direction on the scale which is taken as positive unless followed by a minus sign. As in the case of LOC 2 and TEM 2, closed intervals are represented by giving the boundary points of the interval. The effect of the degree relation (DEG 2) which assigns to A an open degree interval B may be to transform the distribution of (e.g.) heights associated with the attribute name ("tall"), possibly additively or multiplicatively (Cliff, 1959).

The manner relation (MAN) is used to specify categorical or extensive information characterizing an action or state, information not represented by the relations AGT, DAT, INST, OBJ, SOURCE, FAC, GOAL, THEME, LOC, or TEM. The relation MAN corresponds to the attributive relations EXT and CAT defined for objects. Two types of manner relation are defined. The first type of manner relation specifies that the action or state belongs to a class of such actions or states in which the class may be either (1) an ordered class with respect to other such classes or (2) not ordered with respect to other classes (MAN 2). The adverbial relation MAN 1 corresponds to the attributive relation CAT 1 and MAN 2 corresponds to CAT 2. The second type of manner relation assigns an extensive (quantitative) property to an action or state and corresponds to the attributive relation EXT. The extensive manner relation has the general form

$$A \xrightarrow{\text{MAN EXT i}} B$$

where A is an action or state, B designates an attribute scale or an open interval on an attribute scale, and the relation MAN EXT i assigns property B to A. The index i can be 1 or 2 defining the relations corresponding respectively to the relations EXT 1 and EXT 2.

9.3 Logical Structure

9.3.1 General considerations. The logical structure of a text represents in the form of a directed graph a network of binary relations defined on pairs of propositions which are themselves represented as relational structures in the semantic structure graph. Relations defined in the logical structure represent a number of sorts of connectives including conditional relations which render a proposition's truth value conditional on the validity of other propositions; order and proximity relations which constrain the values of attributes, locations, times, degrees or manners for which a proposition is true by making these values relative to values specified in other propositions; and algebraic relations which may be used in conjunction with relations of order, proximity, and equivalence, to constrain attribute values. Conditional connectives may represent relations of logical implication, contrafactual conditional statements in which the contrapositive is not necessarily valid, and causal statements which represent causal relationships which are not necessarily proximal in nature and hence cannot be represented in terms of case relations. In general the relations represented in the logical structure operate on the propositions contained in the semantic structure by specifying interpropositional constraints which restrict the conditions under which the propositions of the semantic structure are valid. The present analysis identifies and defines a number of logical relations which appear to be necessary to represent natural language discourses. The set of relations defining the present logical structure and the operators to be discussed in the following section together define a set of logical elements which may not be represented in terms of any two-valued logic based on first order predicates. Indeed, in addition to requiring a logic which allows for n-order predicates and for statements which vary in probability or degree of confirmation, these elements require a logic which treats contrafactual conditional statements and what Rescher (1964) has called belief-contravening suppositions, causal orderings, and relations defined on propositions which are themselves inherently probabilistic or imprecise (e.g., propositions involving the relations EXT 2, NUM 2, DEG 2, LOC 2, TEM 2).[10]

9.3.2 Conditional relations. Logical relations which may occur in the logical structure graph are listed in Table 9.2. The listed logical relations are classified as conditionals, order and proximity relations, relations of conjunction and alternation, exhaustive differentiation, and algebraic relations. Relations of conjunction, alternation, and exhaustive differentiation are, with the exception of exclusive alternation, represented structurally in the semantic structure graph. Hence, no specific designated relations appear in Table 9.2. Six types of conditional relations are defined: logical implications, bidirectional implications, contrafactual conditional relations, causal relations, definitional relations, and disjunction. An implication is a valid material conditional statement, Thus, the conditional statement

$$\text{"if } p_1 \text{ then } P_2\text{" } (p_1 \xrightarrow{\text{IF}} p_2)$$

is valid, and the contrapositive statement

$$\text{"if not } P_2\text{, then not } P_1\text{" } (-p_2 \xrightarrow{\text{IF}} -p_1)$$

is also valid. A bidirectional implication is the conjunction of two implications:

$$p_1 \xrightarrow{\text{IF}} p_2 \text{ and } p_2 \xrightarrow{\text{IF}} p_1$$

and may be stated "p_1 if and only if p_2" ($p_1 \xleftrightarrow{\text{IFF}} p_2$).

A contrafactual conditional statement

$$(p_1 \xrightarrow{\text{COND}} p_2)$$

Table 9.2

List of Designated Connectives in Logical Structure Graph

I. Conditionals

IMPLICATION	material conditional, "if A then B" & "if -B then -A" are valid	$\xrightarrow{\text{IF}}$
BIDIRECTIONAL IMPLICATION	material biconditional "A if and only if B"	$\xleftrightarrow{\text{IFF}}$
CONTRAFACTUAL CONDITIONAL	contrafactual conditional, "if A then B" is valid, contrapositive, "if -B then -A" may not be valid	$\xrightarrow{\text{COND}}$
CAUSAL	contrafactual conditional, temporal order (see text for other defining characteristics)	$\xrightarrow{\text{CAU}}$
DEFINITIONAL IFF	identity in semantic structure	
DISJUNCTION	there exists no valid conditional connective	$\xrightarrow{\text{DIS}}$

II. Order and Proximity Relations*

STRONG ORDER RELATION	transitive, asymmetric, irreflexive	$\xrightarrow[(\ )]{\text{ORD1}}$
WEAK ORDER RELATION	transitive, antisymmetric, reflexive	$\xrightarrow[(\ )]{\text{ORD2}}$
EQUIVALENCE RELATION	transitive, symmetric, reflexive	$\xleftrightarrow[(\ )]{\text{EQUIV}}$
STRONG PROXIMITY ORDER	intransitive, asymmetric, irreflexive	$\xrightarrow{\text{P-ORD 1}}$
WEAK PROXIMITY ORDER	intransitive, antisymmetric, reflexive	$\xrightarrow{\text{P-ORD 2}}$
PROXIMITY RELATION	intransitive, symmetric, reflexive	$\xleftrightarrow[(\ )]{\text{PROX}}$

Table 9.2 (Cont.)

III.	Conjunction and Alternation		
	OR: UNION - INTERSECTION	exclusive alternation	$OR:[P_1,P_2,\ldots,P_n]$
	& OR: UNION	nonexclusive alternation	
	&: INTERSECTION	conjunction	
IV.	Exhaustive Differentiation		
V.	Algebraic Relations		
	ADDITION		+
	DIFFERENCE		-
	DISTANCE	symmetric relation satisfying positivity, distance from any point to itself is zero, triangle inequality	d

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*If an order or proximity is preceded by a " . ", then the asserted relation is only an approximation (e.g., EQUIV means "approximately equal."

is a statement of the form "if p_1 then p_2" for which the contrapositive is not necessarily valid. A contrafactual conditional statement may or may not be belief contravening. The contrafactual property of some conditional statements (absence of a necessarily valid contrapositive) is due to the failure to completely state all of the premises or hypotheses upon which the validity of p_2 (the consequent) depends. A contrafactual statement is belief contravening if it "draws a consequence from an antecedent that is in fact a belief-contravening hypothesis" (Rescher, 1964, p. 25). In Rescher's (1964) analysis, the problem with contrafactual statements which are belief-contravening is that they are contextually ambiguous, i.e., accepting one proposition of a set of propositions leads to the consequence that other propositions of the set may no longer be accepted and that there is more than one way in which the set of other propositions may be revised. Rescher's method of solution of the problem of contrafactuals involves the extablishment of a principle of acceptance or rejection based on an ordered property of the set of propositions such as probability of confirmation or causal ordering (in the case of causal contrafacturals).

A causal relation connecting two propositions (causal contrafactual relation)

$$p_1 \xrightarrow{\text{CAU}} p_2$$

is a special case of a contrafactual conditional relation in which the relation possesses two properties in addition to the defining properties of the contrafactual conditional relation. The two additional properties are: (1) the contrapositive of a causal relation is necessarily false, and (2) the order of the "antecedent" and "consequent" propositions referred to in the triple

$$p_1 \xrightarrow{\text{CAU}} p_2$$

is fixed by an established causally ordered (or partially ordered) set of factual propositions describing events or states: the antecedent proposition being a "cause" and the consequent being an "effect." The set of causally ordered propositions often will refer to a set of events which are temporally ordered (or partially temporally ordered). The first property above referes to the requirement that

$$p_1 \xrightarrow{\text{CAU}} p_2 \text{ implies that not } p_2 \xrightarrow{\text{CAU}} \text{not } p_1$$

is necessarily false. The causal ordering referred to in the second property is established by means of an analysis of the functional relations among all variables involved in the events or states to which the contrafactual statements refer (Simon and Rescher, 1966). Such an analysis amounts to an identification of a model describing a process within which the relation expressed in the causal contrafactual statement is to be interpreted. If a relation is CAU then it will not be represented as COND, i.e., COND consists of all contrafactual conditional relations which do not satisfy the additional conditions of CAU relations. The following two sentences illustrate COND and CAU relations respectively:

1 If John goes to the store (p_1), he will not have enough money (p_2).

2a If John runs too fast (p_1), he will fall down (p_2).

Sentence 1 is a contrafactual conditional statement in which the contrapositive is not necessarily false. In sentence 2a, the contrapositive is necessarily not valid (just as

$$p_2 \xrightarrow{\text{CAU}} p_1$$

is not valid), and there is a causal order established by an implied functional analysis based on elementary physical principles Sentence 2a also involves a temporal order corresponding to the causal order. Simon and Rescher (1966) have pointed out that the causal sequence of events expressed in sentences such as 2a may be expressed in reverse order as in 2b: "If John fell down, then he must have been running too fast" using the modal "must." "Must" used as logical necessity may be represented by indicating that there is a set of unspecified (deleted) propositions (*) which logically imply a proposition, i.e.,

$$* \xrightarrow{\text{IF}} p_1.$$

Then 2b may be expressed

$$p_2 \xrightarrow{\text{COND}} [* \xrightarrow{\text{IF}} p_1]$$

where * refers to

$$p_1 \xrightarrow{\text{CAU}} p_2.$$

In instances not involving a causal ordering, the unspecified propositions will in general not be identifiable in constructions involving "must." Conditional relations are useful in the representation of other modals (e.g., "can," "ought," "should"). Since the qualifying probability operator (to be defined in the next section) is also involved in representing other modals, they will be discussed in the next section.

The remaining two conditional relations are definitional IFF and the disjunctive logical relation DIS. Definitions are represented in the semantic structure using the IDENTITY relation. The relation DIS connecting two propositions asserts that there exists no valid conditional relation connecting the two propositions. DIS may be indicated in a surface sentence by "even though" or "although." In most instances involving the relation DIS the speaker would be likely to assume that his listener would expect a conditional relation to hold (e.g., in "John went to the beach (p_1) even though it was raining (p_2)"

$$[p_2 \xrightarrow{\text{DIS}} p_1]$$

one would be likely to expect that "since it was raining, John did not go to the beach"

$$[p_2 \xrightarrow{\text{COND}} -p_1].$$

9.3.3 Order and proximity relations. Defining properties of order and proximity relations are summarized in Figure 9.2. Order and proximity relations are binary relations which connect pairs of comparable propositions expressing certain attributive relations (EXT 2, LOC 1, LOC 2, TEM 1, TEM 2, CAT 1, CAT 2), adverbial relations (DEG 1, DEG 2, LOC 1, LOC 2, TEM 1, TEM 2, MAN 1, MAN 2), or quantifiers (NUM 1, NUM 2). Two propositions are comparable if they involve the same relations. The relations listed above are of four types which may be distinguished by the manner in which they assign quantitative (metric) values to the concepts they modify. These three types are: (1) metric: assigning a point value on a metric scale to a concept (e.g., NUM 1, DEG 1, LOC 1, TEM 1), (2) stochastic: associating a probability distribution on a metric scale with a concept (e.g., EXT 2, NUM 2, DEG 2, LOC 2, TEM 2), (3) ordered class: assigning a concept to a class which is ordered r.e. other classes (e.g., CAT 1, MAN 1), and (4) classificatory: no metric properties (e.g., CAT 2, MAN 2). Particular order and equivalence relations must be defined with respect to each of these three types of relations.

Three properties characterize order and proximity relations: transitivity, symmetry, and reflexivity (c.f., Coombs, 1964). An order relation is any transitive relation connecting comparable metric, stochastic, or ordered class propositions. If an order relation is symmetric and reflexive it is an equivalence relation (EQUIV, e.g., "equals"). The negation of an equivalence relation is the symmetric and irreflexive relation - (EQUIV) (e.g., "unequal to"). If an order relation is asymmetric and irreflexive, it is a strong order relation (ORD 1, e.g., "greater than"); if it is antisymmetric and reflexive it is a weak order relation (ORD 2, e.g., "greater than or equal to"). Most order relations connect propositions asserting metric or stochastic relations (i.e., order relations connecting ordered classes rarely occur since ordered classes appear to occur infrequently). Metric order relations are defined on the point values specified by the connected propositions. In comparative constructions, unspecified point values are constrained to satisfy a particular order relation. For example, "John is taller than Sally" constrains the degree of height attributable to John to be greater than that attributable to Sally while it leaves the values of these degrees unspecified. The example is represented as follows:

$$\begin{tikzcd}
\text{[John} \arrow[r, "\text{EXT 1}"] & \text{tall} \arrow[r, "\text{DEG 1}"] & \text{X]} \arrow[d, bend left, "\text{ORD 1}"] \\
\text{[Sally} \arrow[r, "\text{EXT 1}"] & \text{tall} \arrow[r, "\text{DEG 1}"] & \text{Y]}
\end{tikzcd}$$

Stochastic order relations are defined on the distributions of values specified by the connected propositions. Note that the transitivity property of order relations will hold only approximately (or stochastically) for order relations defined on "stochastic propositions." Hence, the notion of transitivity must be replaced by the notion of stochastic transitivity in the definition of order relations. Notions of stochastic transitivity have been utilized extensively in the study of preference among alternatives, particularly among alternatives which have multidimensional attributes which may influence choices (c.f., Tversky, 1969). Stochastic equivalence will be defined as equivalence of the modes of the two distributions (i.e., the most

	Proximity	Order
	INTRANSITIVE	TRANSITIVE
SYMMETRIC		
REFLEXIVE	$\xleftrightarrow{\text{PROX}}$	$\xleftrightarrow{\text{EQUIV}}$
IRREFLEXIVE	$\xleftrightarrow{\text{-(PROX)}}$	$\xleftrightarrow{\text{-(EQUIV)}}$
ASYMMETRIC		
REFLEXIVE	-	-
IRREFLEXIVE	$\xrightarrow{\text{P-ORD 1}}$	$\xrightarrow{\text{ORD 1}}$
ANTISYMMETRIC		
REFLEXIVE	$\xrightarrow{\text{P-ORD 2}}$	$\xrightarrow{\text{ORD 2}}$
IRREFLEXIVE	-	-

Figure 9.2

Properties of Order and Proximity Relations.

probable values). Strong and weak stochastic order relations may be similarly defined. An example of a strong stochastic order relation is the sentence: "Sally is tall, but John is taller" which is represented:

$$\begin{tikzcd}
{[\text{ John}} \arrow[r, "\text{EXT 2}"] & {\text{tall }]} \arrow[d, bend left, "\text{ORD}"] \\
{[\text{ Sally}} \arrow[r, "\text{EXT 2}"] & {\text{tall }]}
\end{tikzcd}$$

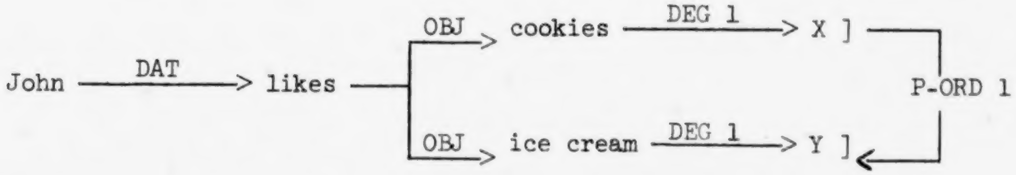
Sentences involving ordered classes must unequivocally treat the ordered classes as categories, e.g., as in "The tall girls are not as tall as the tall boys, but they are fewer in number."

A proximity relation is any intransitive relation connecting comparable propositions. If a proximity relation is symmetric and reflexive it will be called a simple proximity relation (or just a "proximity relation" if no ambiguty results) and denoted PROX, (e.g., "same as," "next to"). The negation of a simple proximity relation is the symmetric and irreflexive relation -(PROX) (e.g., "different from"). If a proximity relation is asymmetric and irreflexive, it is a strong proximity order P-ORD 1 (e.g., "nearer to," "more similar to"); if it is antisymmetric and reflexive it is a weak proximity order (P-ORD 2, e.g., "at least as similar as"). The intransitivity that is a defining property of proximity relations occurs when either (1) the attributive or adverbial relations asserted in the connected propositions are classificatory (non-metric) or (2) the attributive or adverbial relations assign to their concepts a point in a metric space which has dimensionality greater than one (e.g., as in certain locative expressions). Examples of proximity relations (involving unspecified point values) are: (1) (PROX) "Your keys are with your wallet," (2) -(PROX) "Your car is different from mine," (3) (P-ORD 1) "The house is nearer than the church." An example of a stochastic proximity relation is (4) "Your house is near, but the church is nearer." Sentence (1) is represented:

$$\begin{tikzcd}
{[\text{keys}} \arrow[r, "\text{LOC 1}", "(0)"'] & {X]} \arrow[d, bend left, <->, "\text{PROX}"] \\
{[\text{wallet}} \arrow[r, "\text{LOC 1}", "(0)"'] & {Y]}
\end{tikzcd}$$

The other examples involving relative location require the algebraic relation distance and will be discussed later. Examples of proximity relations involving classificatory propositions are: (PROX) "John is married to Alice," "John is a cousin of Alice"; (P-ORD 1) "John likes cookies more than he likes ice cream"; and (P-ORD 2) "John likes cookies at least as much as ice cream." Examples of representations of these sentences are:

$$\begin{tikzcd}
{[\text{ John}} \arrow[r, "\text{CAT 2}"] & {\text{cousin }]} \arrow[d, bend left, <->, "\text{PROX}"] \\
{[\text{ Alice}} \arrow[r, "\text{CAT2}"] & {\text{cousin }]}
\end{tikzcd}$$

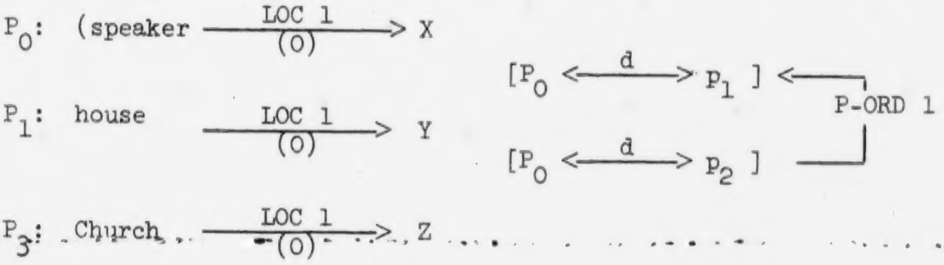


9.3.4 Other logical relations. The remaining logical relations listed in Table 9.2 define relations of conjunction and alternation, exhaustive differentiation, and certain algebraic relations. Exclusive alternation is designated by OR followed in brackets by the list of propositions to which OR applies. Nonexclusive alternation (&OR) requires no particular notation: it is assumed that at any branching point in the semantic structure graph, a structure containing any subset of the propositions is valid. Conjunction (&) is represented in the semantic structure graph by enclosing the set of concepts or propositions whose conjunction is to be represented in a box. Exhaustive differentiation refers to situations in which the set of relations which differentiate a concept set are exhaustive, i.e., no elements remain in the set which do not belong to the subsets specified by the given relations. This situation is most likely to occur with collective nouns and is represented by introducing an additional relation

$$\xrightarrow{\text{CAT 2}} \phi$$

(ϕ represents the null set). Algebraic relations may be defined on metric quantities to correspond to the familiar algebraic relations. The distance relation d is defined as any symmetric relation which is always positive, such that the distance of any point to itself is zero, and such that the triangle inequality holds, i.e., d (A,B) + d (A,C) $\geq$ d (A,C). The remainder of this section will illustrate how order and proximity relations may be used with the algebraic relations difference and distance to represent various statements of relative location and relative time.

9.3.5 Relative location. Statements about relative location are of three principal types: relative position, direction, and orientation (Leech, 1969). One sort of relative position, adjacency, has already been discussed (examples (1) and (2) on the previous page). Another sort of relative position, relative distance, is involved in examples (3) and (4) on the same page. Example (3) may be represented using the distance relation as follows:



Here, P_0 is the point of orientation with respect to which the relative distance is measured. In example (4) "Your house is near, but the church is nearer," "near" assigns to the distance

$$P_0 \xleftrightarrow{\;d\;} P_1$$

a degree within an open interval and the proximity order is stochastic. Sentence (4) is represented:

$$\begin{tikzcd}
{[\,P_0 \xleftrightarrow{\;d\;} P_1\,]} \arrow[r, "\text{DEG 2}"] & \text{near} \\
{[\,P_0 \xleftrightarrow{\;d\;} P_2\,]} \arrow[r, "\text{DEG 2}"] & \text{near} \arrow[u, "\text{P-ORD}"']
\end{tikzcd}$$

Statements of direction such as "The bird is above John" involve establishing from a reference location a line or reference axis which is labelled by designating either the positive or negative direction (from the reference location) on the line. Thus in "The bird is above John," John is the reference location through which an (above-below) axis is established and on which the positive direction relative to John is "above." The example is represented:

$$\begin{tikzcd}
{[\,\text{bird} \xrightarrow[(1)]{\text{LOC 2}} \text{above}\,]} \arrow[d, "\text{ORD-1}"] \\
{[\,\text{John} \xrightarrow[(1)]{\text{LOC 1}} 0\,]}
\end{tikzcd}$$

The relevant dimensionality of the locative relation is fixed at one designating the objects "bird" and "John" as falling on the line for which John is at the origin, and the bird is somewhere on the open interval "above." Since the dimensionality is one, the relation ORD 1 applies. Statements of orientation involve such prepositions as "across," "through," "beyond," and "on this side of " as in the "The farm is beyond the village and "The house is across the road"; and establish an ordering of objects in terms of relative distance from a point of orientation (P_0) along a line on which all objects fall. Thus the first example is represented:

$$P_0\text{: (speaker)} \xrightarrow[(1)]{\text{LOC 1}} 0$$

$$P_1\text{: farm} \xrightarrow[(1)]{\text{LOC 1}} f$$

$$P_2\text{: village} \xrightarrow[(1)]{\text{LOC 1}} v$$

$$\begin{tikzcd}
{[\,P_0 \xleftrightarrow{\;d\;} P_1\,]} \arrow[d, "\text{ORD 1}"] \\
{[\,P_0 \xleftrightarrow{\;d\;} P_2\,]}
\end{tikzcd}$$

9.3.6 Relative time. Statements of relative time may be classified as before-after statements, statements of relative duration, and "while" statements (c.f., Leech, 1969). Examples of before-after statements are "I saw him when he saw me" and "The final exam comes after the midterm." Statements involving measured intervals are also possible as "He arrived five minutes after the lecture started." The general form for before-after statements is

$$p_1\colon\ S_1 \xrightarrow{\text{TEM 1}} t_1 \qquad\qquad p_1 \overset{R}{\text{———}} p_2$$

$$p_2\colon\ S_2 \xrightarrow{\text{TEM 1}} t_2$$

where R is an order relation and S_1 and S_2 are propositions. The general form for measured intervals between events is

$$[\ p_1 - p_2\ ] \xleftrightarrow{\text{EQUIV}} X$$

units. The statement "She studied for a longer time than I" is a statement of relative duration. Such statements are represented using the relation

$$S \xrightarrow{\text{TEM 2}} T$$

to indicate that S occurred during the time interval T. The general form for statements of relative duration is

$$p_1\colon\ S_1 \xrightarrow{\text{TEM 2}} T_1 \qquad\qquad p_1 \overset{R}{\text{———}} p_2$$

$$p_2\colon\ S_2 \xrightarrow{\text{TEM 2}} T_2$$

where R is an order relation. "While" statements involve order relations defined on closed temporal intervals where the boundaries of the closed intervals may be unspecified. Examples are such sentences as "She was at home while I was at the lecture" (co-extensive intervals of time), "When I looked away, Soren grabbed the toy" (point contained within a temporal interval), "John's ideas have changed since he went to the lecture" ("until" and "since"), and "John talked to us while we were on vacation" (temporal interval contained within an interval of time). The general form of each of these cases is as follows:

1. co-extensive intervals:

$$p_1\colon\ S_1 \xrightarrow{\text{TEM 2}} [t_1,\ t_2] \qquad\qquad p_1 \xleftrightarrow{\text{EQUIV}} p_2$$

$$p_2\colon\ S_2 \xrightarrow{\text{TEM 2}} [t_1',\ t_2'] \qquad\qquad p_1(t_1) \xleftrightarrow{\text{EQUIV}} p_2(t_1)$$

2. point contained within an interval:

$$p_1\colon\ S_1 \xrightarrow{\text{TEM 2}} [t_1,\ t_2] \qquad p_1(t_1) \xleftarrow{\text{ORD 2}} p_2 \xrightarrow{\text{ORD 2}} p_1(t_2)$$

$$p_2\colon\ S_2 \xrightarrow{\text{TEM 1}} t$$

3. "until" and "since":

until $\quad p_1\colon\ S_1 \xrightarrow{\text{TEM 1}} t_1 \qquad S_2 \xrightarrow{\text{TEM 2}} \begin{bmatrix} \text{present} \\ t_1 \end{bmatrix}$

since $\quad p_1\colon\ S_1 \xrightarrow{\text{TEM 1}} t_1 \qquad S_2 \xrightarrow{\text{TEM 2}} \begin{bmatrix} t_1 \\ \text{present} \end{bmatrix}$

4. interval contained within an interval:

(p_1 and p_2 as in 1. above)

$$p_1 \xrightarrow{\text{ORD 1}} p_2$$

$$p_1(t_1) \xleftarrow{\text{ORD 2}} p_2(t'_1)$$

$$p_1(t_2) \xrightarrow{\text{ORD 2}} p_2(t'_2)$$

The expression p_1 (t_1) is used to represent the proposition asserting that the interval of time given by p_1 started at time t_1 and $p_1(t_2)$ indicates the time at which the event ended. Interpretation of the example sentences in terms of their appropriate general forms is left to the reader.

9.4 Operators on Semantic and Logical Relations

9.4.1 General considerations. As was indicated in the earlier discussion of basic semantic properties of texts, the relations represented in the semantic and logical structures of a text may be transformed or "operated upon" in various ways. Particular properties of relations which may be transformed are truth-value, time relative to the factual present, and completeness of a relational structure. Specific operations on relations which effect these properties are identified in Table 9.3.

9.4.2 Operators on truth-value. Operations on truth value are negation, denoted -(R), where R is a relation to which the operator is applied; qualification of a relation, denoted QUAL(R); and interrogation, denoted ?(R). The negation operator (truth-value operator) applied to a relation results in a proposition which is not valid. The operation of qualifying a relation (probability operator) attaches to each proposition containing that relation a probability that the proposition is valid. Probability operators are likely to be represented in the surface sentence by modals such as "may," "might," etc. Since different qualifying constructions in the surface sentence may result in different probability values (or distributions of probability values) the representation of the operator QUAL(R) includes the qualifying modal word X written in parentheses below the operator. Analyses of a number of modals will be presented below. The interrogative operator ?(R) interrogates the truth-value of the proposition containing the interrogated relation. Since it is also possible to interrogate a concept (see the essay which is analyzed in the next section for examples), two sorts of interrogation may occur. The interrogation operation may be expressed by prefixing "whether" or "whether or not," or by means of the interrogative transformation. Interrogation of concepts is expressed by means of wh-questions.

2.4.3 Types of negation. The operators on truth value, negation and qualification, may be used in conjunction with the negative quantifier

Table 9.3

Operators on Relations in Semantic Structure Graph and Connectives in Logical Structure Graph*

I. Negation of Relation		
	TRUTH-VALUE OPERATOR	$\xrightarrow{-(R)}$
II. Qualification of Relation		
	PROBABILITY OPERATOR	$\xrightarrow{QUAL(R)}$
III. Tense		
	TEMPORAL OPERATOR	$\xrightarrow[(X)]{TEM(R)}$
IV. Deleted or Non-Specific Node		
	NODE DELETION OPERATOR	$*\xrightarrow{*(R)}$
V. Conditional Truth-Value		
	CONDITIONAL OPERATOR	$\xrightarrow[(X)]{COND(R)}$
VI. Interrogated Truth-Value		
	INTERROGATIVE OPERATOR	$\xrightarrow{?(R)}$
VII. Aspect		
	ASPECT	$\xrightarrow[(X)]{ASPCT(R)}$

---

* X further designates the type of operator, e.g., X may be a qualifying word, tense, type of conditional, etc.

and certain types of relations involving negative direction on a metric scale (i.e., NUM 2, EXT 2, DEG 2, LOC 2, TEM 2, in which the reference direction is labelled (-) negative) to generate a classification of types of negation (where by "negation" is meant that the resulting proposition expresses either a contradictory or contrary to another proposition which is construed as "positive"). This classification is related to Clark's (1972) discussion of types of negation in English in which a distinction was made between explicit negation [which "can co-occur with 'any' in the same clause and with 'either' as a final tag when the negative is in the second of two 'and'-conjoined clauses" (Clark, 1972, p. 42)] and implicit negation (which cannot), and between full negation (contradictories) and quantifier negation (contraries). In terms of the operators and relations named above, a classification of types of negation can be made on the basis of (1) the type of negating operation: presence of a specific negating operator or relation vs. implicit negation given by a negatively defined metric scale, and (2) type of relation "operated upon": determinate (i.e., not stochastic) vs. stochastic. The classification is as follows:

1. negating operation:

   a. explicit negation:

relational:	- operator	["strong"]
	QUAL and - operators	["weak"]
conceptual:	∅ quantifier	["strong"]
	NUM 2 (-) quantifier	["weak"]

   b. implicit negation:

relational:	A R B (-) where B (-) is negative direction on B scale and R is EXT 2 DEG 2, LOC 2, or TEM 2
conceptual	A R B (-) where R is the quantifier NUM 2 which assigns negative direction on the numerosity scale

2. type of relation "operated upon":

a. full negation:	negative operator applied to a determinate (non-stochastic) relation
b. stochastic negation:	negative operator applied to an implicitly positive stochastic relation (defined in the positive direction)

Here "stochastic negation" corresponds to Clark's "quantifier negation." This classification results in the following types of negation

1. "strong conceptual negation"	e.g. "none," "no people"
2. "weak conceptual negation"	e.g. "few people"
3. "strong full negation"	e.g. "he isn't present"
4. "weak full negation"	e.g. "he may not be present"

5. "implicit negation" e.g. "little " "below," "seldom"
6. "strong stochastic negation" e.g. "not many," "not above"
7. "weak stochastic negation" e.g. "may not be many," "may not be above"

9.4.4 *Tense and aspect*. As indicated in the discussion of the temporal relation TEM, tense and aspect operators denote the time of an event relative to the factual present, while the temporal relation may specify either simple or relative time: relative to a point of orientation which may not coincide with the factual present. While tense and aspect can be represented structurally in terms of relations of relative time, to provide a sort of "shorthand" they will be represented by means of the temporal operator, denoted

$$\xrightarrow[(X)]{\text{TEM(R)}}$$

where R is a relation and X denotes a tense name (*viz*. past, future); and the aspect operator

$$\xrightarrow[(X)]{\text{ASPCT(R)}},$$

where X identifies the particular aspect (*viz*. Continuous, Completive, Inceptive, Cessive, Habitual, and Iterative). If no operator appears on a relation, it will be assumed to be the simple present. Since the operators TEM and ASPCT can be represented structurally, they are fundamentally different from the other operators which operate on truth value. Particular tense and aspect operators will be defined in terms of their structural equivalents. The definitions follow:

1. Tense: P_1: $A \xrightarrow{\text{TEM 1}} t$ p_o: speaker $\xrightarrow{\text{TEM 1}}$ present (t_o)

   a. *present* $p_o \xleftrightarrow{\text{EQUIV}} p_1$

   b. *past* $p_1 \xleftarrow{\text{ORD 1}} p_o$

   c. *future* $p_o \xleftarrow{\text{ORD 1}} p_1$

2. Aspect

   a. *simple* "he walks" $A \xrightarrow{\text{TEM 1}} t_o$ (present)

   b. *continuous* "he is walking" $A \xrightarrow{\text{TEM 2}} t_o$ (present)

   c. *completive* "he has been walking" $A \xrightarrow{\text{TEM 2}} \boxed{\begin{matrix} t_1 \\ t_1 \end{matrix}}$

$$P\ (t_2) \xleftarrow{\text{ORD 1}} p_o$$

d. inceptive "he begins walking" $A \xrightarrow{\text{TEM 2}} \begin{bmatrix} t_o & \text{(present)} \\ t_1 & \end{bmatrix}$

e. cessive "he stops walking" $A \xrightarrow{\text{TEM 2}} \begin{bmatrix} t_1 & \\ t_o & \text{(present)} \end{bmatrix}$

f. habitual "he always walks" $A \xrightarrow{\text{TEM 1}} t \text{ (EACH)}$

g. iterative "he repeatedly walks"

$$\begin{tikzcd}
P_1: & A \arrow[r, "\text{TEM 1}"] & t_1 \\
P_2: \arrow[u, "\text{ORD 1}"'] & A \arrow[r, "\text{TEM 1}"] & t_2 \\
P_3: \arrow[u, "\text{ORD 1}"'] & A \arrow[r, "\text{TEM 1}"] & t_3 \\
\vdots & \vdots & \\
P_n: & A \arrow[r, "\text{TEM 1}"] & t_n
\end{tikzcd}$$

$$P_1 \xleftarrow{\text{ORD 1}} P_o \xleftarrow{\text{ORD 1}} P_n$$

9.4.5 Conditional and node deletion operators. The conditional operator COND(R) renders the validity of each proposition containing the relation R conditional on the validity of other propositions. The specific conditional constraints may be specified in the logical structure graph. If these conditions are not explicit, they may be indicated as unspecified (deleted) in the logical structure by means of the node deletion operator *(R). Thus, in the sentence "The satellite must return to earth," the specific conditions which render it necessary that the satellite return to earth are unspecified. The sentence is represented

$$* \xrightarrow{*(F)} p_1$$

where * refers to the unspecified set of conditions, the node deletion operator has been applied to the relation IF (i.e., the antecedent conditions have been deleted), and p_1 is the proposition corresponding to the sentence "The satellite returns to earth." In addition to the modals "must" and "have to" (as logical necessity), the node deletion operator is likely to be represented in the surface sentence in the form of participles, gerunds, truncated passives, infinitives e.g., deleted agent), and pronouns with unclear antecedents. In addition, the node deletion operator is required in comparatives and in some statements of relative time and location. Often letters will be used to represent the deleted node in the graph structures. If the antecedent conditions are neither specified in the logical structure nor represented as deleted, a conditional proposition containing a conditional relation is taken to have hypothetical status. An hypothetical proposition is considered to be true only for purposes of argument; it is neutral with respect to its actual truth or falsity.

9.4.6 Modals. To illustrate some uses of the operators *(R), QUAL(R), and COND(R) and to provide representations of some frequently occurring structures involving these operators, descriptions of logico-semantic representations of some modal auxiliaries which express possibility or logical necessity will now be presented. The modals to be considered are "may," "might," "must," "can," "ought," "would," "should," and "could" as they express possibility or logical necessity. The logical structures to be considered may be classified as (1) those involving no antecedent conditions, (2) those involving unstated (deleted) antecedent conditions, (3) those involving unstated qualified antecedent conditions, and (4) those involving stated antecedent conditions. Within each of these classes, the (consequent) proposition may be either unqualified or qualified. A list of the logical structures corresponding to this classification together with their associated modal expressions and an example of each follows:

1. no antecedent conditions:

a.	unqualified (consequent)		$A \xrightarrow{R} B$
b.	qualified (consequent)	"may," "might," "can" (as possibility)	$A \xrightarrow{QUAL(R)} B$

2. unstated antecedent conditions:

a.	unqualified consequent	"must," "has to"	$* \xrightarrow{*(IF)} [A \xrightarrow{COND(R)} B]$
b.	qualified consequent	"can" (as ability)	$* \xrightarrow{*(IF)} [A \xrightarrow{\substack{COND \\ QUAL(R)}} B]$

3. unstated qualified antecedent conditions:

a.	unqualified consequent	"may have to," "ought to," "should"	$* \xrightarrow{\substack{QUAL \\ *(IF)}} [A \xrightarrow{COND(R)} B]$
b.	qualified consequent	"may be able to," "ought to be able to," "should be able to"	$* \xrightarrow{\substack{QUAL \\ *(IF)}} [A \xrightarrow{\substack{COND \\ QUAL(R)}} B]$

4. stated antecedent conditions:

a.	unqualified consequent	"would," "must," "would have to"	$p \xrightarrow{\text{COND}} [A \xrightarrow{\text{COND(R)}} B]$
b.	qualified consequent	"should," "might," "could" (as possibility)	$p \xrightarrow{\text{COND}} [A \xrightarrow{\substack{\text{COND}\\ \text{QUAL(R)}}} B]$
c.	ability consequent	"could"	$p \xrightarrow{\text{COND}} [* \xrightarrow{*\text{(IF)}} [A \xrightarrow{\substack{\text{COND}\\ \text{QUAL(R)}}} B]$

Sentence examples of each logico-semantic structure are:

1b He may go to the store (it is possible for him to go).
2a The satellite must eventually return to earth. (it is logically necessary).
2b He can lift the weight. (There are conditions under which it is possible).
3a The satellite may have to return to earth. (There may be conditions which render it necessary).
3b He may be able to lift the weight. (There may be conditions under which it is possible).
4a If he told you that, he would be lying.
4b If he told you that, he might be lying.
4c If he were ten pounds heavier, he could lift the weight.

Note that if sentence 4a were expressed as "If he told you that, he was lying," the speaker has asserted both a proposition of type 4a and a proposition asserting that the consequent ("John was lying") actually occurred.[11] Finally, note that the logical structures listed under headings 2 to 4 above may be negated in more than one way, i.e., if two relations are represented in the structure, either may be negated. This fact enables one to represent the differences between such sentences as "He doesn't have to go":

$$* \xrightarrow{-*\text{(IF)}} [A \xrightarrow{\text{COND(R)}} B]$$

and "He mustn't go":

$$* \xrightarrow{*\text{(IF)}} [A \xrightarrow{\text{COND-(R)}} B]$$

9.5 Analysis of an Essay on School Desegregation

The discussion of semantic and logical structures and operators on relations represented in these structures has dealt up to this point principally with representations of single sentences as propositions, and with logical connectives defined on pairs of propositions. This section will complete the discussion of general principles for representing the semantic and logical structures of texts by presenting a detailed analysis of an example text consisting of an essay on school desegregation together with a description of additional principles which are required for representing those properties of texts which extend beyond sentence boundaries. Of specific concern for an analysis of texts (as opposed to constituent sentences considered individually) is the establishment of principles related to three of the "basic" properties of texts which were identified at the outset: principles for establishing unique sequences of semantic relations which constitute a dominance order, principles for establishing an hierarchical semantic structure (a "branching tree" structure) such that each branch constitutes an ordered sequence of relations, and principles governing the selection of inexplicit inferrable semantic and logical relational structures for inclusion in the structural representation of a text.

The analysis of a text involves roughly the following sequence of steps:

1. Generation of a semantic representation of each constituent sentence,
2. identification of intersentential connectives and representation of any logical relations which are defined on the propositions resulting from (1),
3. identification of explicit superordinate concepts,
4. identification of certain inexplicit structural elements including:
    a. superordinate concepts which are necessary to complete the semantic hierarchy,
    b. deleted nodes in the semantic and logical structures,
    c. inexplicit elements in relative constructions (i.e., constructions involving order or proximity relations), and
    d. inexplicit inferrable semantic and logical relations connecting explicit concepts or propositions which are either necessary to complete the semantic hierarchy or necessary to produce a maximally connected logical or semantic structure graph,
5. construction of the semantic and logical structure graphs from the results of the above steps.

Each of these steps will now be considered and then the entire procedure will be illustrated with an analysis of a sample essay.

The semantic representation of a single sentence containing a verb phrase and noun phrases in various case relations to the verb involves first breaking the sentence into its verb phrase and noun phrase constituents and then identifying the case relations which characterize the relation of each noun phrase to the verb. Identification of case relations also involves identifying any relations whose associated concept nodes have been deleted (see the discussion of the node deletion operator for examples). The order of the semantic structure graph of the sentence follows the causal ordering described in the discussion of the case relations: the agent (or reflexive agent) precedes the verb and other cases (which either explicate the action or are "resultive") follow the verb and are not ordered among themselves. If no animate agent is required, the instrument (or reflexive instrument) precedes the verb. Noun phrases which follow the verb are not ordered. This partially ordered semantic structure corresponds to a basic sentence paraphrase: that paraphrase which is most closely related to the underlying semantic structure (and which presumably requires less complicated rules of expression to generate it). Such a paraphrase will always be active and declarative. Nonspecified concepts will be designated by symbols and interrogated concepts or relations appropriately marked. A basic sentence is not necessarily affirmative or simple. It is often useful to generate such a paraphrase as an intermediate step in obtaining a semantic representation of a sentence. At this point in the analysis it is also desirable to adopt a single lexical designator for any concept which occurs repeatedly across sentences. Once the relations between the constituent noun phrases and the verb have been represented, the structure of each constituent phrase is represented using appropriate attributive relations, quantifiers, or adverbial relations. Attributive relations are ordered only if changing the order does *not* result in an acceptable paraphrase. A constituent phrase may be replaced by an embedded clause which is itself represented structurally as an embedded proposition.

Once the constituent sentences in a text have been represented semantically, superordinate concepts are examined for all propositions, and superordinate concepts among them are identified. To obtain a tree-structure, it may be necessary to identify inexplicit superordinate concepts from which explicit concept sets may be differentiated. Once the necessary superordinate concept sets have been identified, the hierarchical semantic structure can be constructed. Solely to avoid triviality, the convention is adopted that the single left-most concept set be the smallest concept class from which all concepts to the right of it in the hierarchy may be differentiated. The same convention is also adopted for subordinate semantic hierarchies. In completing the semantic structure graph, other inexplicit concepts and relations may have to be represented, especially in representing deleted nodes and relations, relative constructions, and modal expressions. Each concept in the semantic structure is given a number uniquely identifying its location in the hierarchy: as one proceeds from left to right, each "layer" of the tree is represented by an additional digit and within a layer, branches are numbered consecutively. For ease of identification, the first branches to the right may receive letters (as in the example to be presented).

The nodes connected by relations in the logical structure graph are propositions represented in the semantic structure and are denoted in the logical structure by code numbers locating the proposition in the semantic structure. The general form of the code is A(____/ ____, ____, . . .), where A locates the main branch, the space before the slash contains the number of the left-most concept contained in the proposition, and the space to the right of the slash contains the numbers (separated by commas) of all terminal concepts in the proposition. Represented first in the logical structure are all explicit conditional relations, order and proximity relations, and other relations defined in the logical structure. In some instances, logical relations may be represented in the semantic structure as well, especially embedded logical relations and order and proximity relations occurring in comparatives. When the explicit logical structure is complete, additional inferrable semantic and logical relations are constructed which are necessary to produce a maximally connected semantic or logical structure graph. As the analysis proceeds, all relations are labelled and any operators on relations are marked.

While the brief description just presented is intended to orient the reader to the steps involved in the analysis of a text, the method is most readily understood by working from a particular text to its representation. It is desirable that such an example be sufficiently complex to illustrate repeatedly a large number of points of semantic analysis which have been described in the preceding pages. The example text whose analysis is presented was used to develop scoring procedures based on the present semantic analysis. In choosing to work with a long and relatively "complex" text, it was felt that any procedure which was capable of representing such a text would be likely to be applicable to most other texts. The essay which was selected is based on an essay by Dodson (1963) entitled "On Ending DeFacto Segregation" and is a substantially edited version of that text. The essay is in eight paragraphs; the structure of each paragraph is represented for convenience in a separate Figure. The text of the essay follows:

1. Because the dominant people in a community are comfortable in their power role and because their status depends on the existing community structure, which they have created, they will not relinquish this structure without resistance. Therefore, a community confronting desegregation will necessarily experience conflict in some degree. Unfortunately, if a community is not actually confronted with desegregation, it will make little preparation for desegregation and, consequently will make little preparation for the conflict which desegregation entails.

2. Now, the question of who goes to school with whom is not decided by educators. This question is largely a political matter, and because it is largely a political matter, it is usually decided by lawyers, judges, politicians, and community leaders. If power, not educational merit, determines who goes to school with whom, then educators may study the question and interpret the decision, even if they cannot be the decision makers.

3. Since the initial stages of desegregation involve pressure groups which do not include educators, it is important that

there be a clear statement of policy on desegregation, and it is important that this policy be rooted firmly in the authority of the community. In other words, educators need to feel the support of the authority of the community and to feel secure that this authority is legitimate. In addition, educators need to feel that the politicians are operating on their own initiative and not being pushed by pressure groups.

4. Naturally, if groups who oppose desegregation feel that by hollering they will get a hearing, they are going to holler. Therefore, implementers of public policy must move from a clear statement of policy on desegregation and must move with unequivocal mandates. Sometimes these mandates are from the State Department of Education, other times they are from the courts. At other times they must be wrought out of the heat of community controversy.

5. Although educators do not decide the question of who is going to school with whom, they do have the responsibility of interpreting educational matters to politicians. Therefore, educators must be clear about what they believe good education to be. Unfortunately, educators are ambivalent about the merits of a desegregated educational experience for all children as well as for black children.

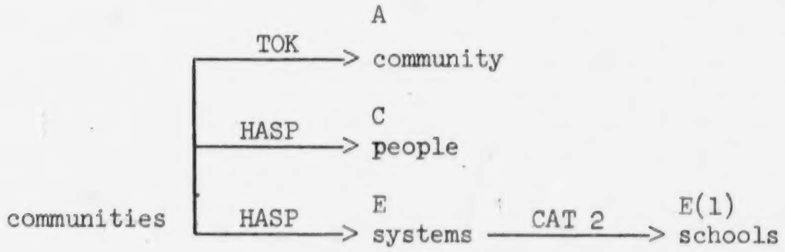
6. Further, educators are confused about the import of the de facto segregated school. Some educators believe there is nothing wrong with segregated schools provided that they are not the result of assignment because of race and provided that they offer as high a quality of education as do the other schools which are not segregated. And they believe this even though there is little evidence to indicate that a de facto segregated school can be made equal in its educational program. If the entire community believe a "Jim Crow" school is inferior, then it is inferior. Therefore, the requirement that a youth attend that school violates his civil rights.

7. As a last point, educators must possess more clarity about the basic factors of growth and development. Some school systems capitalize on the disadvantages of black children which are due to their traumas of the past, and group on a so called "ability basis," thus providing a high degree of segregation. Psychologists have written perceptively of the art of matching up the maturation phases of youth's growth with experiences appropriate to each phase. Not the least important of these phases of maturation is the development of self-other. It is important for a youth to know himself against other selves. It is also important for the range of that "self" to be increasingly widened.

8. One of the major things children learn in today's world is how to hide: how to hide in lily-white suburbs, how to hide

> in homogeneous redevelopment projects. In addition, children learn how to hide in the neighborhood school. All of a sudden the neighborhood school has become sacred and the nearer black children get to it, the more sacred it becomes. The community school was never intended to be a "turf" which shuts out life. However, it was intended to be a place where all the community's children would go to school together. The real issue before educators is how to lead all the community's children toward real experiences with each other so that they develop the skills of citizenship commensurate with the times in which they live.

The semantic and logical structure graphs for the essay on school desegregation are presented in Figures 9.3-10. The left-most superordinate concept ("communities") is not represented in these Figures. The superordinate structure is as follows:



The reader will note in studying the representation of this essay that the extent of the inferred structure which has been represented is minimal, being confined to that which is required to generate the semantic hierarchy and to represent certain regularly occurring structures involving inexplicit (deleted) elements. The inexplicit structure which may be represented is the set of all propositions inferrable from the explicit structure. In general, such a structure is not likely to be representable in closed form. In addition, such an endeavor will inevitably lead to representing lexical elements semantically, thus leading us to depart from our more limited objective of representing only the "structural" as opposed to the lexical meaning of a text. However, it may eventually be important to incorporate more of the "inferred" structure into the semantic and logical structures. For example, it may be desirable to represent inferences which may be generated by a subject with high probability such as certain presuppositions and semantic representations of certain frequently occurring lexical items.

Figure 9.3(a)

Semantic Structure Graph for Essay on School Desegregation, paragraph 1

PARAGRAPH ONE

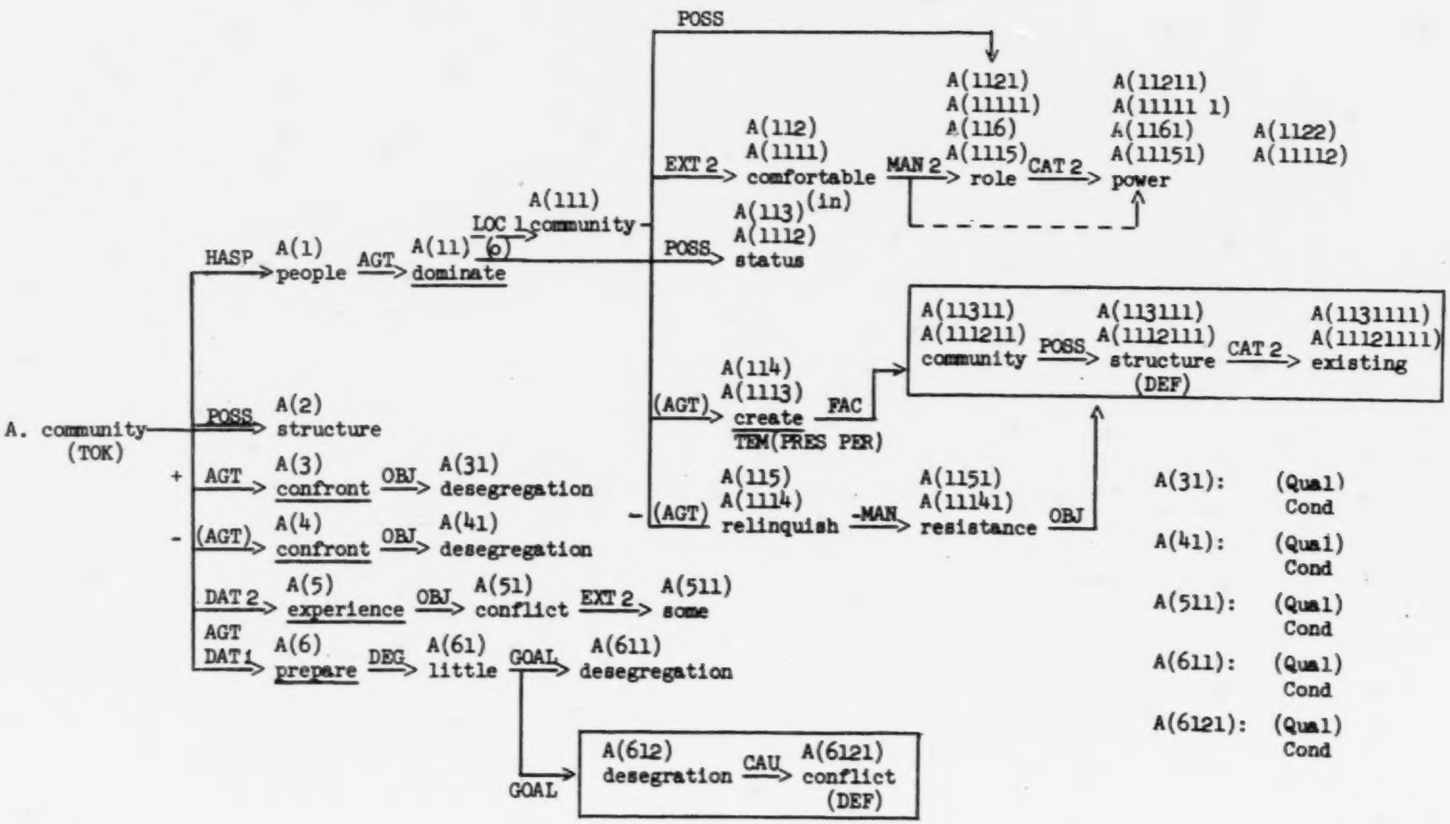

A. community (TOK)
HASP
A(1) people
AGT
A(11) dominate
LOC 1 (o)
A(111) community
POSS
EXT 2
A(112) A(1111) comfortable
(in)
MAN 2
A(1121) A(11111) A(116) A(1115) role
CAT 2
A(11211) A(11111 1) A(1161) A(11151) power
A(1122) A(11112)
POSS
A(113) A(1112) status
(AGT)
A(114) A(1113) create
TEM(PRES PER)
FAC
A(11311) A(111211) community
POSS
A(113111) A(1112111) structure (DEF)
CAT 2
A(1131111) A(11121111) existing
- (AGT)
A(115) A(1114) relinquish
-MAN
A(1151) A(11141) resistance
OBJ
POSS
A(2) structure
+ AGT
A(3) confront
OBJ
A(31) desegregation
- (AGT)
A(4) confront
OBJ
A(41) desegregation
DAT 2
A(5) experience
OBJ
A(51) conflict
EXT 2
A(511) some
AGT DAT 1
A(6) prepare
DEG
A(61) little
GOAL
A(611) desegregation
GOAL
A(612) desegration
CAU
A(6121) conflict (DEF)
A(31): (Qual) Cond
A(41): (Qual) Cond
A(511): (Qual) Cond
A(611): (Qual) Cond
A(6121): (Qual) Cond

Figure 9.3(b)

Logical Structure Graph for Essay on School Desegregation, paragraph 1

PARAGRAPH ONE

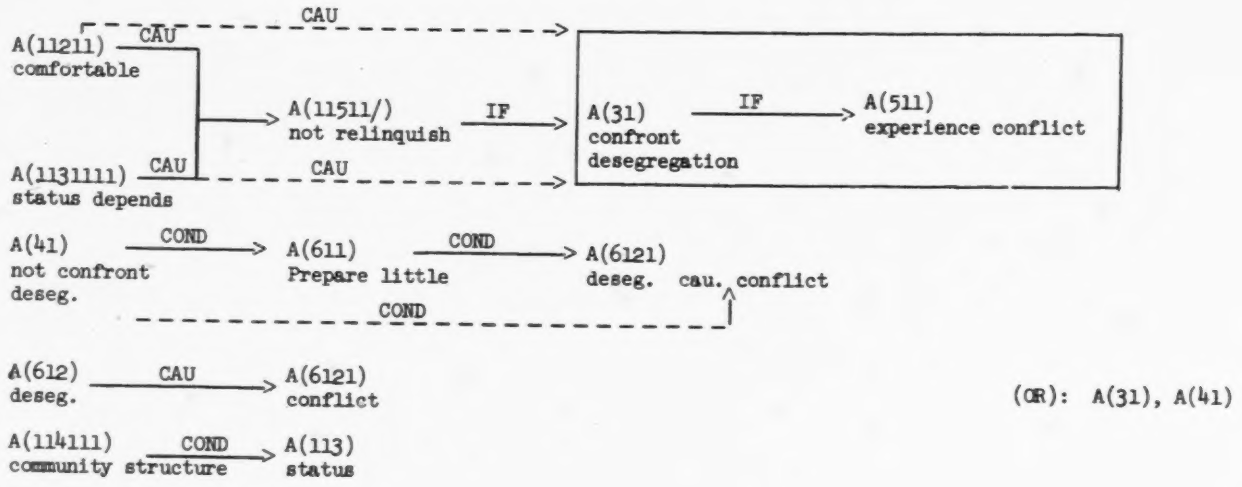

A(11211)
comfortable
CAU
CAU
A(11511/)
not relinquish
IF
A(1131111)
status depends
CAU
CAU
A(31)
confront
desegregation
IF
A(511)
experience conflict
A(41)
not confront
deseg.
COND
A(611)
Prepare little
COND
A(6121)
deseg. cau. conflict
COND
A(612)
deseg.
CAU
A(6121)
conflict
A(114111)
community structure
COND
A(113)
status
(OR): A(31), A(41)

Figure 9.4(a)

Semantic Structure Graph for Essay on School Desegregation, paragraph 2

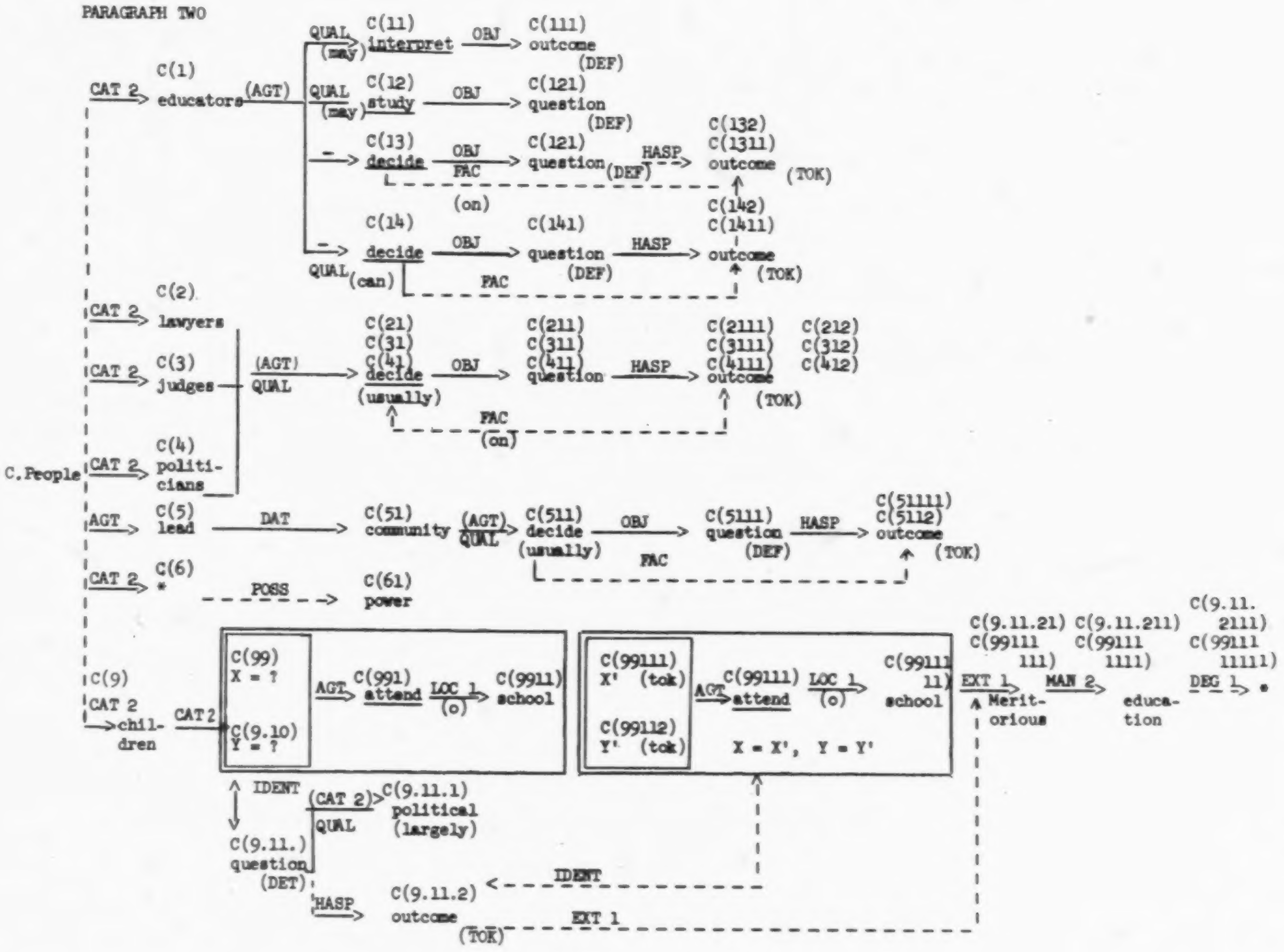

PARAGRAPH TWO
C.People
CAT 2
C(1)
educators
(AGT)
QUAL
(may)
C(11)
interpret
OBJ
C(111)
outcome
(DEF)
C(12)
study
C(121)
question
C(13)
decide
FAC
(on)
HASP
C(132)
C(1311)
(TOK)
C(14)
(can)
C(141)
C(142)
C(1411)
C(2)
lawyers
C(3)
judges
C(4)
politi-
cians
C(21)
C(31)
C(41)
(usually)
C(211)
C(311)
C(411)
C(2111)
C(3111)
C(4111)
C(212)
C(312)
C(412)
AGT
C(5)
lead
DAT
C(51)
community
C(511)
C(5111)
C(51111)
C(5112)
C(6)
*
POSS
C(61)
power
C(9)
chil-
dren
C(99)
X = ?
C(9.10)
Y = ?
C(991)
attend
LOC 1
(o)
C(9911)
school
C(99111)
X' (tok)
C(99112)
Y' (tok)
C(99111)
attend
C(99111
11)
X = X', Y = Y'
IDENT
C(9.11.)
question
(DET)
C(9.11.1)
political
(largely)
C(9.11.2)
EXT 1
C(9.11.21)
C(99111
111)
Merit-
orious
MAN 2
C(9.11.211)
C(99111
1111)
educa-
tion
C(9.11.
2111)
C(99111
11111)
DEG 1
*

Figure 9.4(b)

Logical Structure Graph for Essay on School Desegregation, paragraph 2

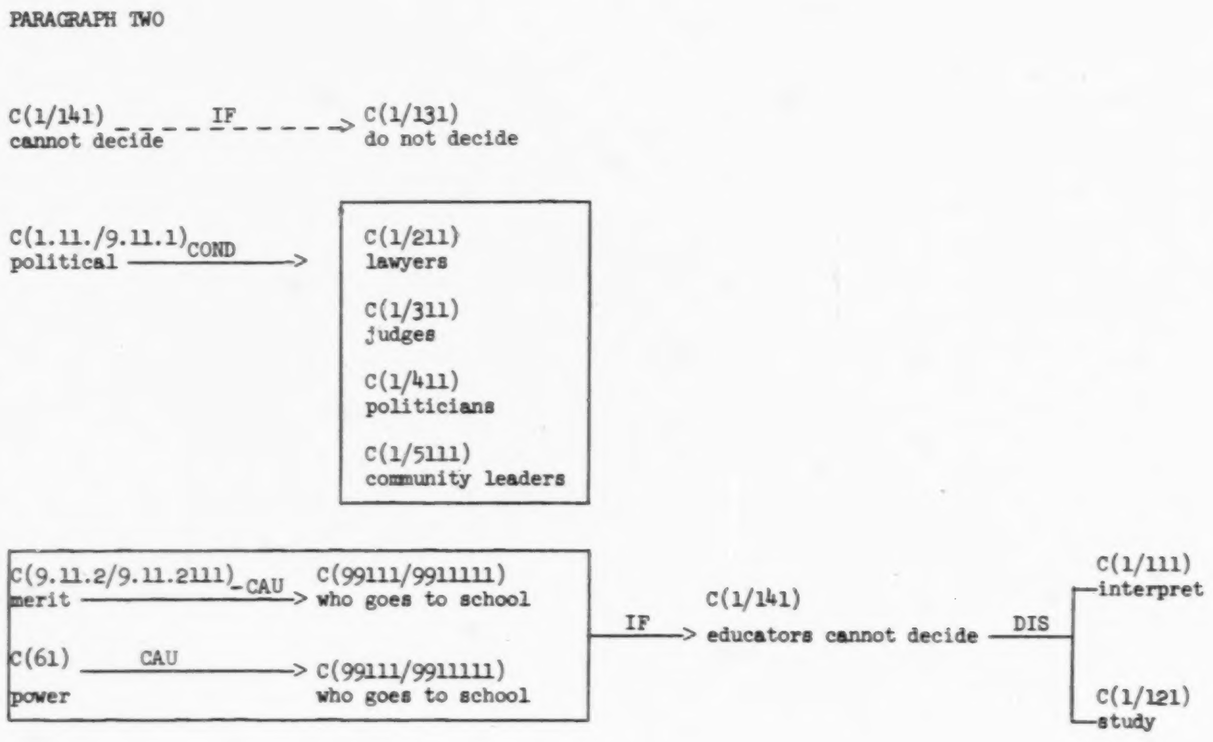

PARAGRAPH TWO
C(1/141)
cannot decide
IF
C(1/131)
do not decide
C(1.11./9.11.1)
political
COND
C(1/211)
lawyers
C(1/311)
judges
C(1/411)
politicians
C(1/5111)
community leaders
C(9.11.2/9.11.2111)
merit
CAU
C(99111/9911111)
who goes to school
C(61)
power
CAU
C(99111/9911111)
who goes to school
IF
C(1/141)
educators cannot decide
DIS
C(1/111)
interpret
C(1/121)
study

Figure 9.5(a)

Semantic Structure Graph for Essay on School Desegregation, paragraph 3

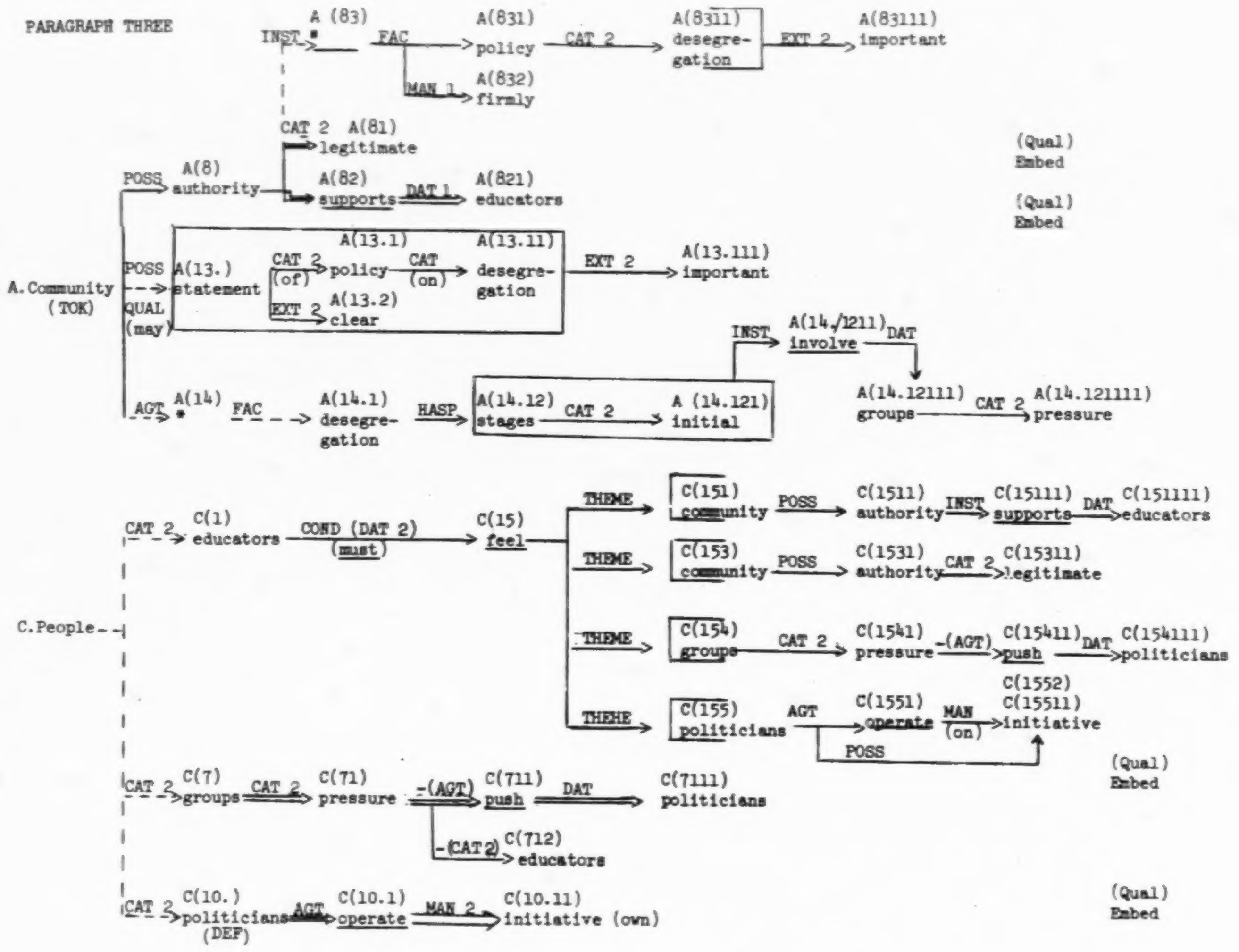

PARAGRAPH THREE
INST
A (83)
*
FAC
A(831)
policy
CAT 2
A(8311)
desegre-
gation
EXT 2
A(83111)
important
MAN 1
A(832)
firmly
CAT 2
A(81)
legitimate
POSS
A(8)
authority
A(82)
supports
DAT 1
A(821)
educators
(Qual)
Embed
(Qual)
Embed
A.Community
(TOK)
POSS
QUAL
(may)
A(13.)
statement
CAT 2
(of)
A(13.1)
policy
CAT
(on)
A(13.11)
desegre-
gation
EXT 2
A(13.2)
clear
EXT 2
A(13.111)
important
INST
A(14./1211)
involve
DAT
AGT
A(14)
*
FAC
A(14.1)
desegre-
gation
HASP
A(14.12)
stages
CAT 2
A (14.121)
initial
A(14.12111)
groups
CAT 2
A(14.121111)
pressure
C.People
CAT 2
C(1)
educators
COND (DAT 2)
(must)
C(15)
feel
THEME
C(151)
community
POSS
C(1511)
authority
INST
C(15111)
supports
DAT
C(151111)
educators
THEME
C(153)
community
POSS
C(1531)
authority
CAT 2
C(15311)
legitimate
THEME
C(154)
groups
CAT 2
C(1541)
pressure
-(AGT)
C(15411)
push
DAT
C(154111)
politicians
THEME
C(155)
politicians
AGT
C(1551)
operate
MAN
(on)
C(1552)
C(15511)
initiative
POSS
(Qual)
Embed
CAT 2
C(7)
groups
CAT 2
C(71)
pressure
-(AGT)
C(711)
push
DAT
C(7111)
politicians
-(CAT 2)
C(712)
educators
CAT 2
C(10.)
politicians
(DEF)
AGT
C(10.1)
operate
MAN 2
C(10.11)
initiative (own)
(Qual)
Embed

Figure 9.5(b)

Logical Structure Graph for Essay on School Desegregation, paragraph 3

PARAGRAPH THREE

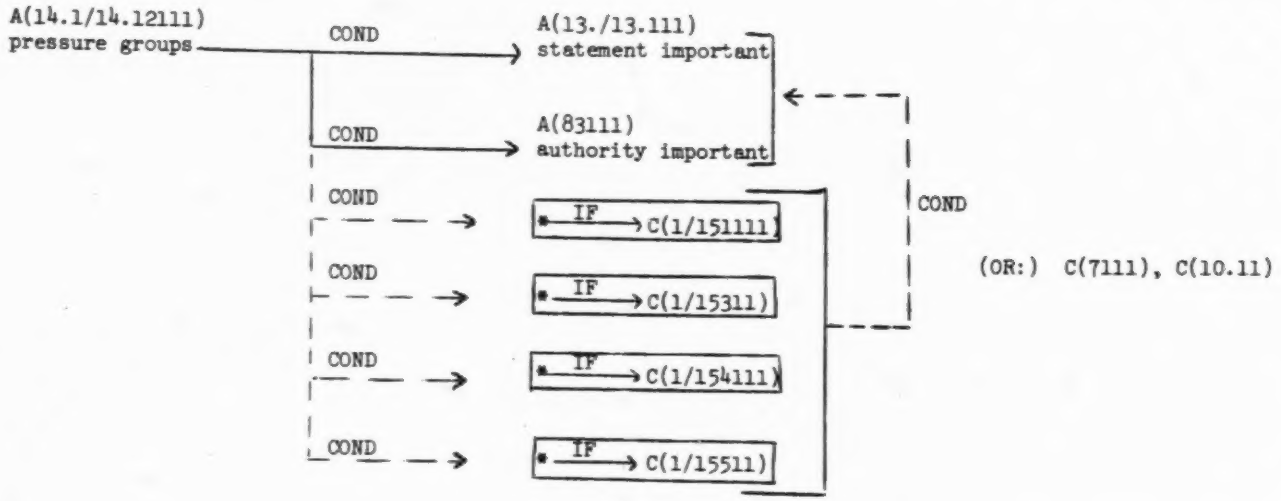

A(14.1/14.12111)
pressure groups
COND
A(13./13.111)
statement important
COND
A(83111)
authority important
COND
IF
C(1/151111)
COND
IF
C(1/15311)
COND
IF
C(1/154111)
COND
IF
C(1/15511)
COND
(OR:) C(7111), C(10.11)

Figure 9.6(a)

Semantic Structure Graph for Essay on School Desegregation, Paragraph 4

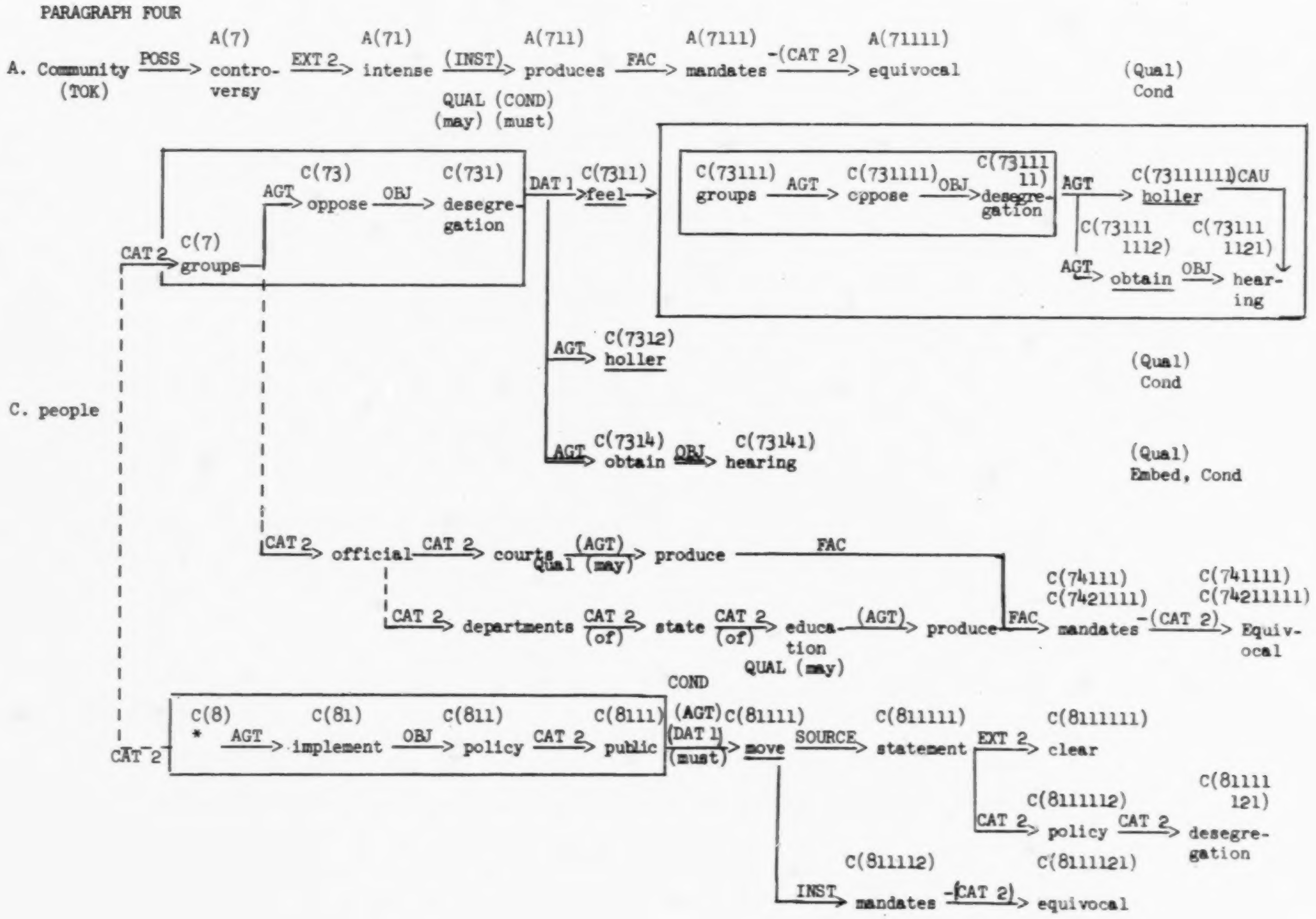

PARAGRAPH FOUR
A. Community (TOK)
POSS
A(7) contro-versy
EXT 2
A(71) intense
(INST)
QUAL (COND) (may) (must)
A(711) produces
FAC
A(7111) mandates
-(CAT 2)
A(71111) equivocal
(Qual) Cond
C(7) groups
CAT 2
AGT
C(73) oppose
OBJ
C(731) desegre-gation
DAT 1
C(7311) feel
C(73111) groups
AGT
C(731111) oppose
OBJ
C(7311111) desegre-gation
AGT
C(73111111) holler
CAU
C(731111112) obtain
AGT
OBJ
C(731111121) hear-ing
AGT
C(7312) holler
(Qual) Cond
C. people
AGT
C(7314) obtain
OBJ
C(73141) hearing
(Qual) Embed, Cond
CAT 2
official
CAT 2
courts
(AGT) Qual (may)
produce
FAC
CAT 2
departments
CAT 2 (of)
state
CAT 2 (of)
educa-tion
(AGT)
QUAL (may)
produce
FAC
C(74111) C(7421111) mandates
-(CAT 2)
C(741111) C(74211111) Equiv-ocal
COND
CAT 2
C(8) *
AGT
C(81) implement
OBJ
C(811) policy
CAT 2
C(8111) public
(AGT) (DAT 1) (must)
C(81111) move
SOURCE
C(811111) statement
EXT 2
C(8111111) clear
CAT 2
C(8111112) policy
CAT 2
C(81111121) desegre-gation
INST
C(811112) mandates
-(CAT 2)
C(8111121) equivocal

Figure 9.6(b)

Logical Structure Graph for Essay on School Desegregation, paragraph 4

PARAGRAPH FOUR

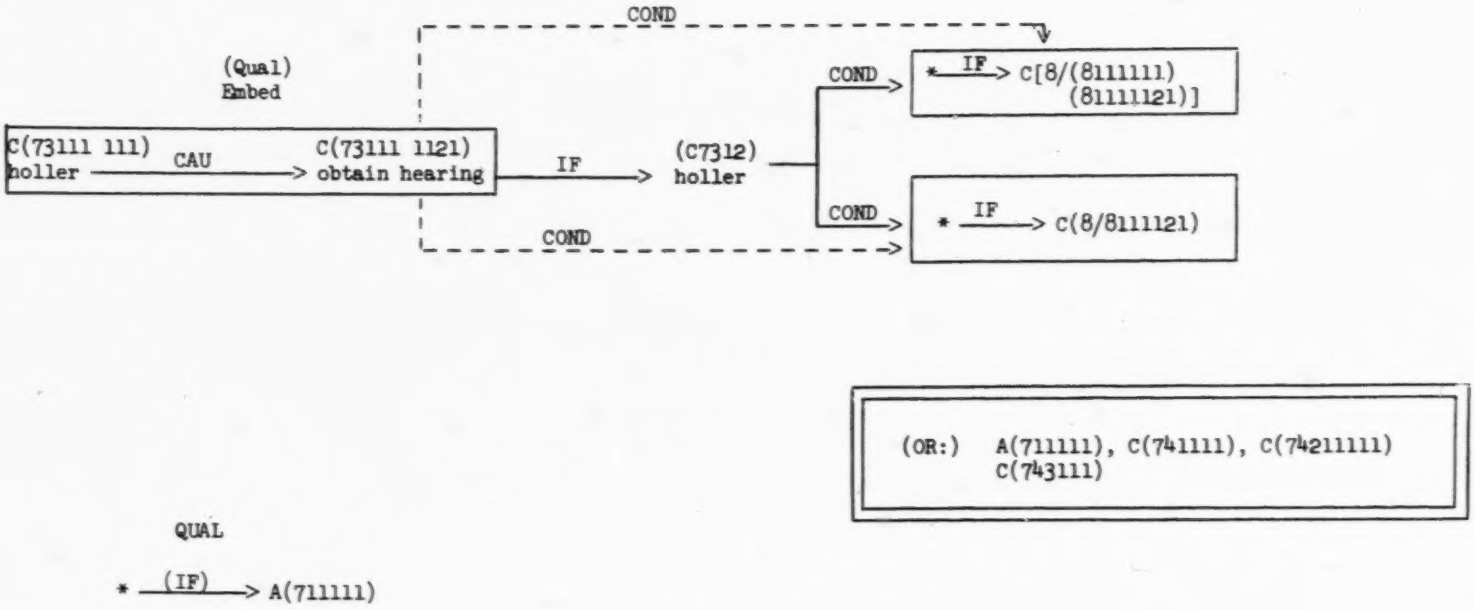

COND
(Qual)
Embed
C(73111 111)
holler
CAU
C(73111 1121)
obtain hearing
IF
(C7312)
holler
COND
* IF > C[8/(8111111)
(81111121)]
COND
* IF > C(8/8111121)
COND
(OR:) A(711111), C(741111), C(74211111)
C(743111)
QUAL
* (IF) > A(711111)

Figure 9.7

Semantic and Logical Structure Graphs for Essay on School Desegregation, paragraph 5

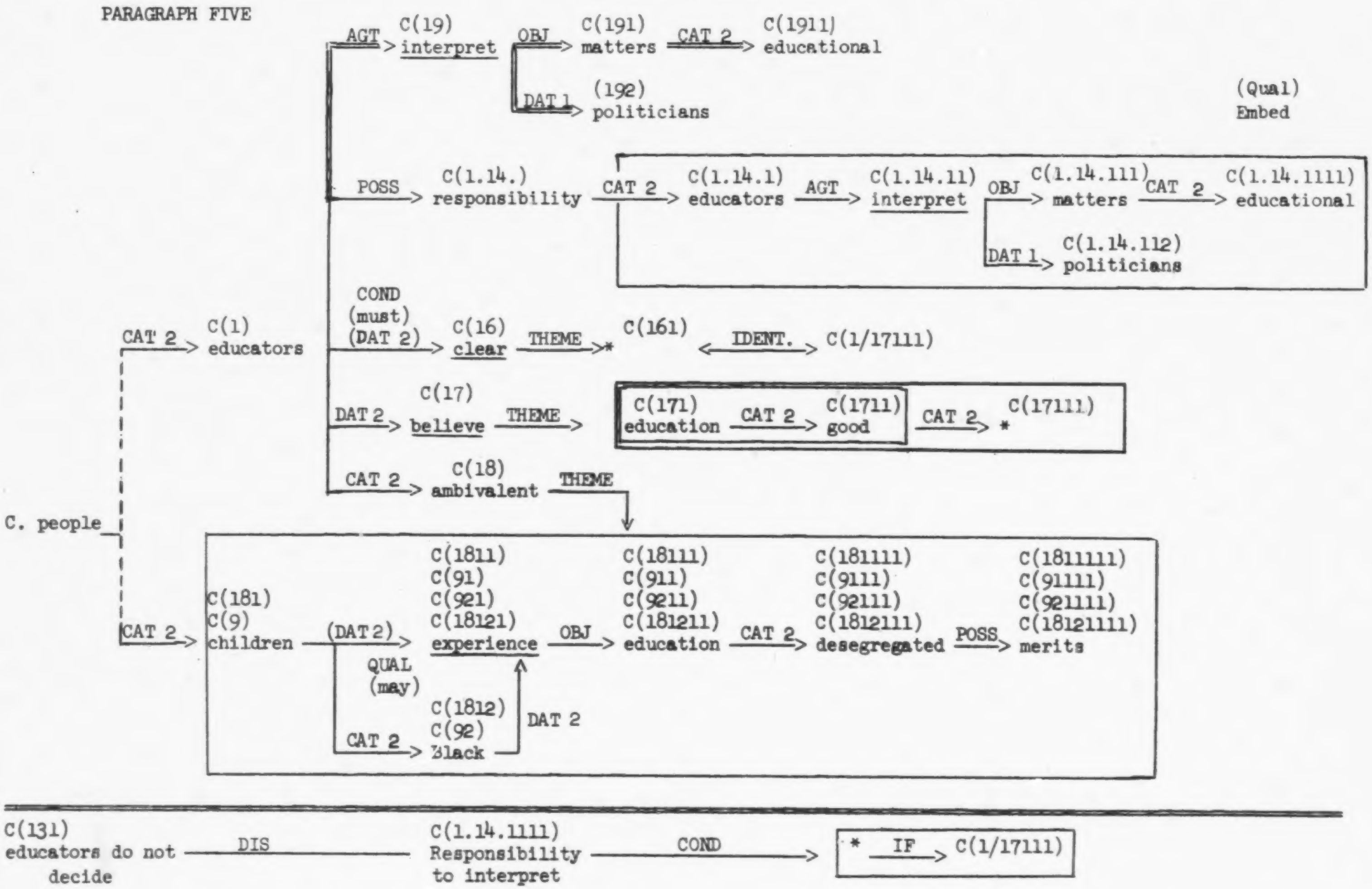

PARAGRAPH FIVE
AGT
C(19) interpret
OBJ
C(191) matters
CAT 2
C(1911) educational
DAT 1
(192) politicians
(Qual) Embed
POSS
C(1.14.) responsibility
CAT 2
C(1.14.1) educators
AGT
C(1.14.11) interpret
OBJ
C(1.14.111) matters
CAT 2
C(1.14.1111) educational
DAT 1
C(1.14.112) politicians
CAT 2
C(1) educators
COND (must) (DAT 2)
C(16) clear
THEME
*
C(161)
IDENT.
C(1/17111)
DAT 2
C(17) believe
THEME
C(171) education
CAT 2
C(1711) good
CAT 2
*
C(17111)
CAT 2
C(18) ambivalent
THEME
C. people
CAT 2
C(181) C(9) children
(DAT 2)
C(1811) C(91) C(921) C(18121) experience
QUAL (may)
CAT 2
C(1812) C(92) Black
DAT 2
OBJ
C(18111) C(911) C(9211) C(181211) education
CAT 2
C(181111) C(9111) C(92111) C(1812111) desegregated
POSS
C(1811111) C(91111) C(921111) C(18121111) merits
C(131) educators do not decide
DIS
C(1.14.1111) Responsibility to interpret
COND
* IF C(1/17111)

Figure 9.8(a)

Semantic Structure Graph for Essay on School Desegregation, paragraph 6

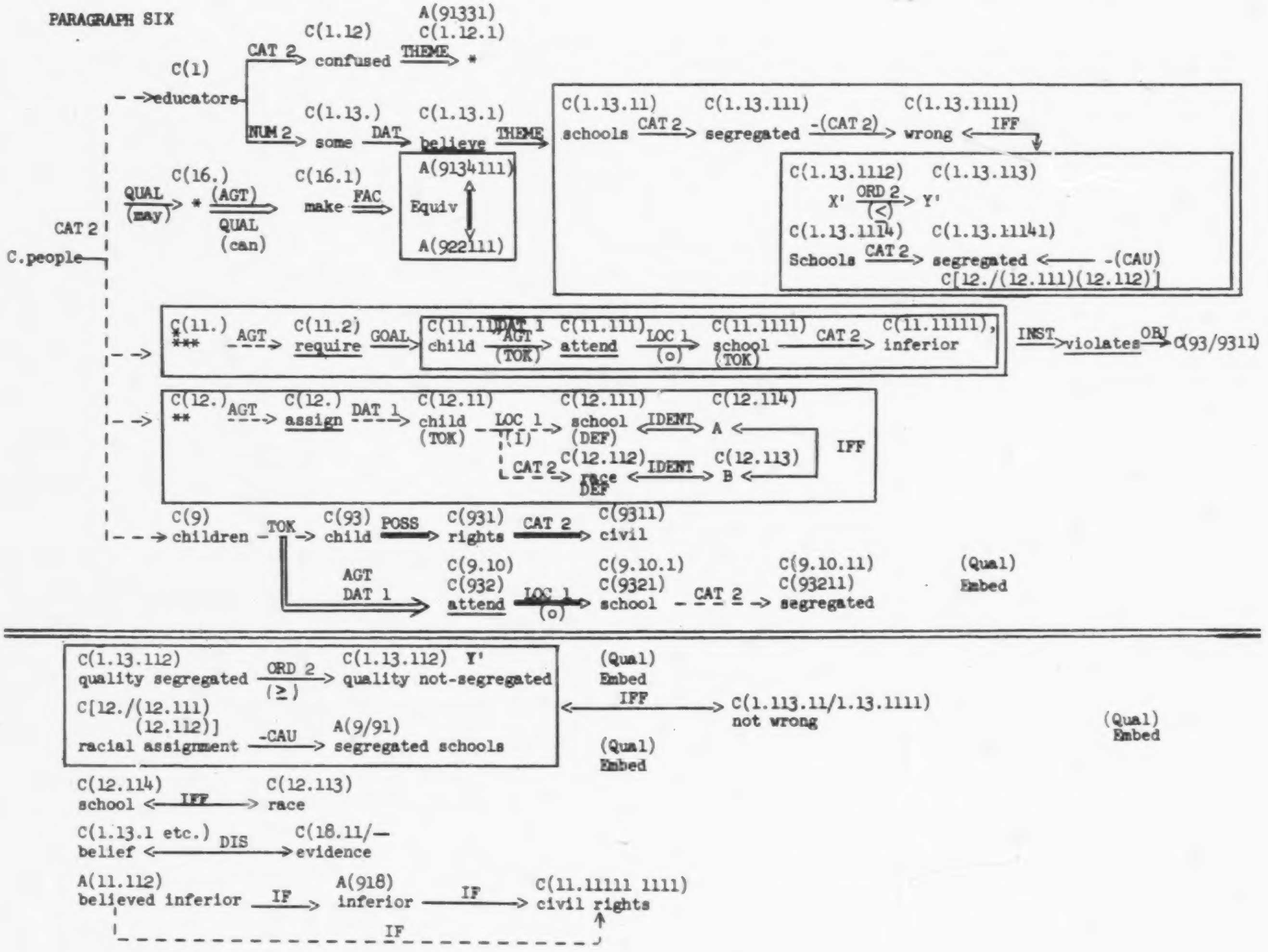

PARAGRAPH SIX
C(1)
educators
CAT 2
C(1.12)
confused
THEME
A(91331)
C(1.12.1)
*
NUM 2
C(1.13.)
some
DAT
C(1.13.1)
believe
THEME
C(1.13.11)
schools
CAT 2
C(1.13.111)
segregated
-(CAT 2)
C(1.13.1111)
wrong
IFF
C(1.13.1112)
X'
ORD 2
(<)
Y'
C(1.13.113)
C(1.13.1114)
Schools
CAT 2
C(1.13.11141)
segregated
-(CAU)
C[12./(12.111)(12.112)]
C.people
CAT 2
QUAL
(may)
C(16.)
*
(AGT)
QUAL
(can)
C(16.1)
make
FAC
A(9134111)
Equiv
A(922111)
C(11.)
***
AGT
C(11.2)
require
GOAL
C(11.11)
child
DAT 1
AGT
(TOK)
C(11.111)
attend
LOC 1
(o)
C(11.1111)
school
(TOK)
CAT 2
C(11.11111),
inferior
INST
violates
OBJ
C(93/9311)
C(12.)
**
AGT
C(12.)
assign
DAT 1
C(12.11)
child
(TOK)
LOC 1
(I)
C(12.111)
school
(DEF)
IDENT
C(12.114)
A
CAT 2
C(12.112)
race
DEF
IDENT
C(12.113)
B
IFF
C(9)
children
TOK
C(93)
child
POSS
C(931)
rights
CAT 2
C(9311)
civil
AGT
DAT 1
C(9.10)
C(932)
attend
LOC 1
(o)
C(9.10.1)
C(9321)
school
CAT 2
C(9.10.11)
C(93211)
segregated
(Qual)
Embed
C(1.13.112)
quality segregated
ORD 2
(≥)
C(1.13.112)
Y'
quality not-segregated
C[12./(12.111)
(12.112)]
racial assignment
-CAU
A(9/91)
segregated schools
(Qual)
Embed
IFF
C(1.113.11/1.13.1111)
not wrong
(Qual)
Embed
(Qual)
Embed
C(12.114)
school
IFF
C(12.113)
race
C(1.13.1 etc.)
belief
DIS
C(18.11/—
evidence
A(11.112)
believed inferior
IF
A(918)
inferior
IF
C(11.11111 1111)
civil rights
IF

Figure 9.8(b)

Semantic and Logical Structure Graphs for Essay on School Desegregation, paragraph 6

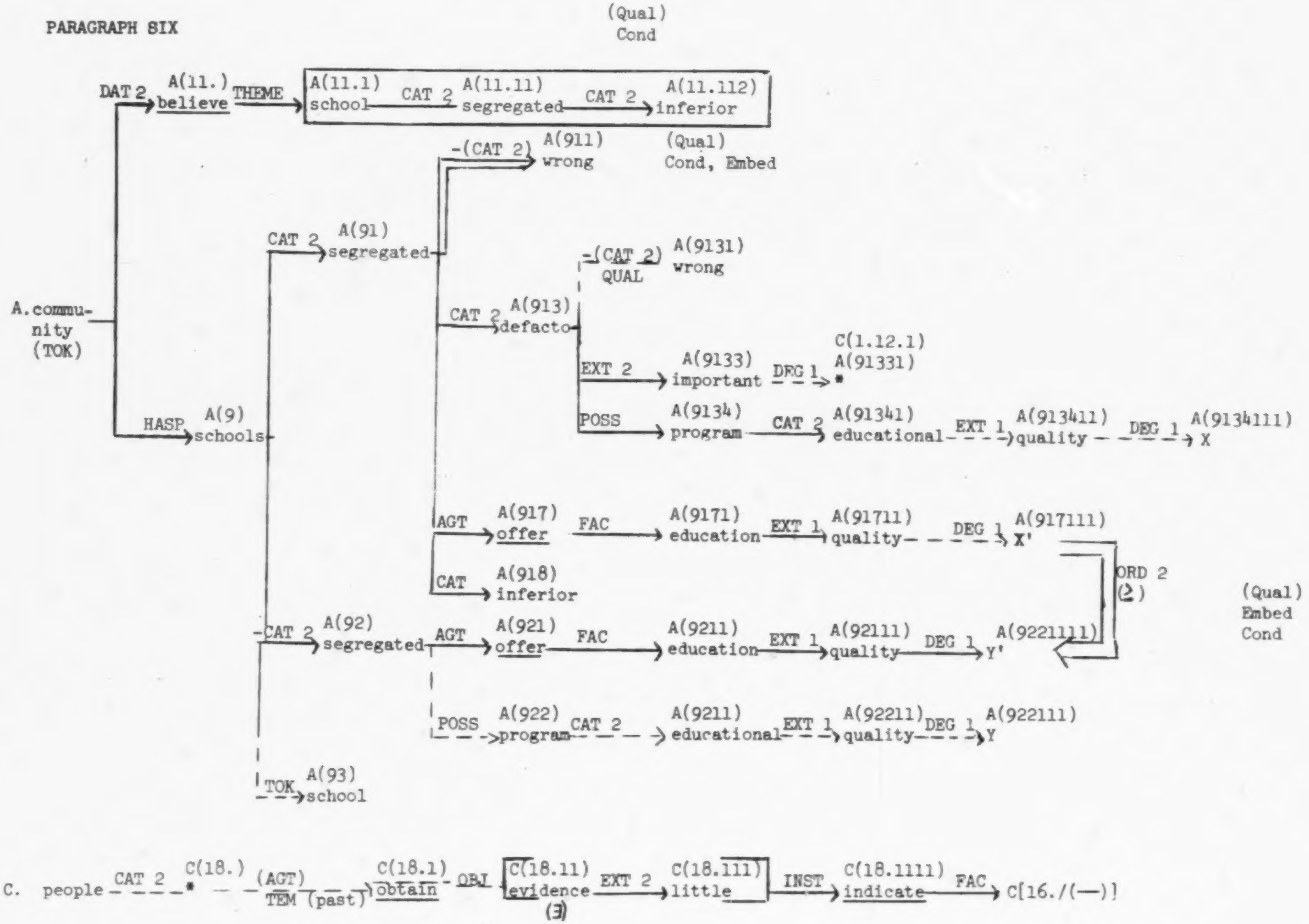

PARAGRAPH SIX
(Qual)
Cond
A.community (TOK)
DAT 2
A(11.)
believe
THEME
A(11.1)
school
CAT 2
A(11.11)
segregated
CAT 2
A(11.112)
inferior
-(CAT 2)
A(911)
wrong
(Qual)
Cond, Embed
CAT 2
A(91)
segregated
-(CAT 2)
QUAL
A(9131)
wrong
CAT 2
A(913)
defacto
EXT 2
A(9133)
important
DEG 1
C(1.12.1)
A(91331)
*
HASP
A(9)
schools
POSS
A(9134)
program
CAT 2
A(91341)
educational
EXT 1
A(913411)
quality
DEG 1
A(9134111)
X
AGT
A(917)
offer
FAC
A(9171)
education
EXT 1
A(91711)
quality
DEG 1
A(917111)
X'
ORD 2
(2)
CAT
A(918)
inferior
(Qual)
Embed
Cond
-CAT 2
A(92)
segregated
AGT
A(921)
offer
FAC
A(9211)
education
EXT 1
A(92111)
quality
DEG 1
A(9221111)
Y'
POSS
A(922)
program
CAT 2
A(9211)
educational
EXT 1
A(92211)
quality
DEG 1
A(922111)
Y
TOK
A(93)
school
C. people
CAT 2
C(18.)
*
(AGT)
TEM (past)
C(18.1)
obtain
OBJ
C(18.11)
evidence
(3)
EXT 2
C(18.111)
little
INST
C(18.1111)
indicate
FAC
C[16./(—)]

Figure 9.9(a)

Semantic Structure Graph for Essay on School Desegregation, paragraph 7

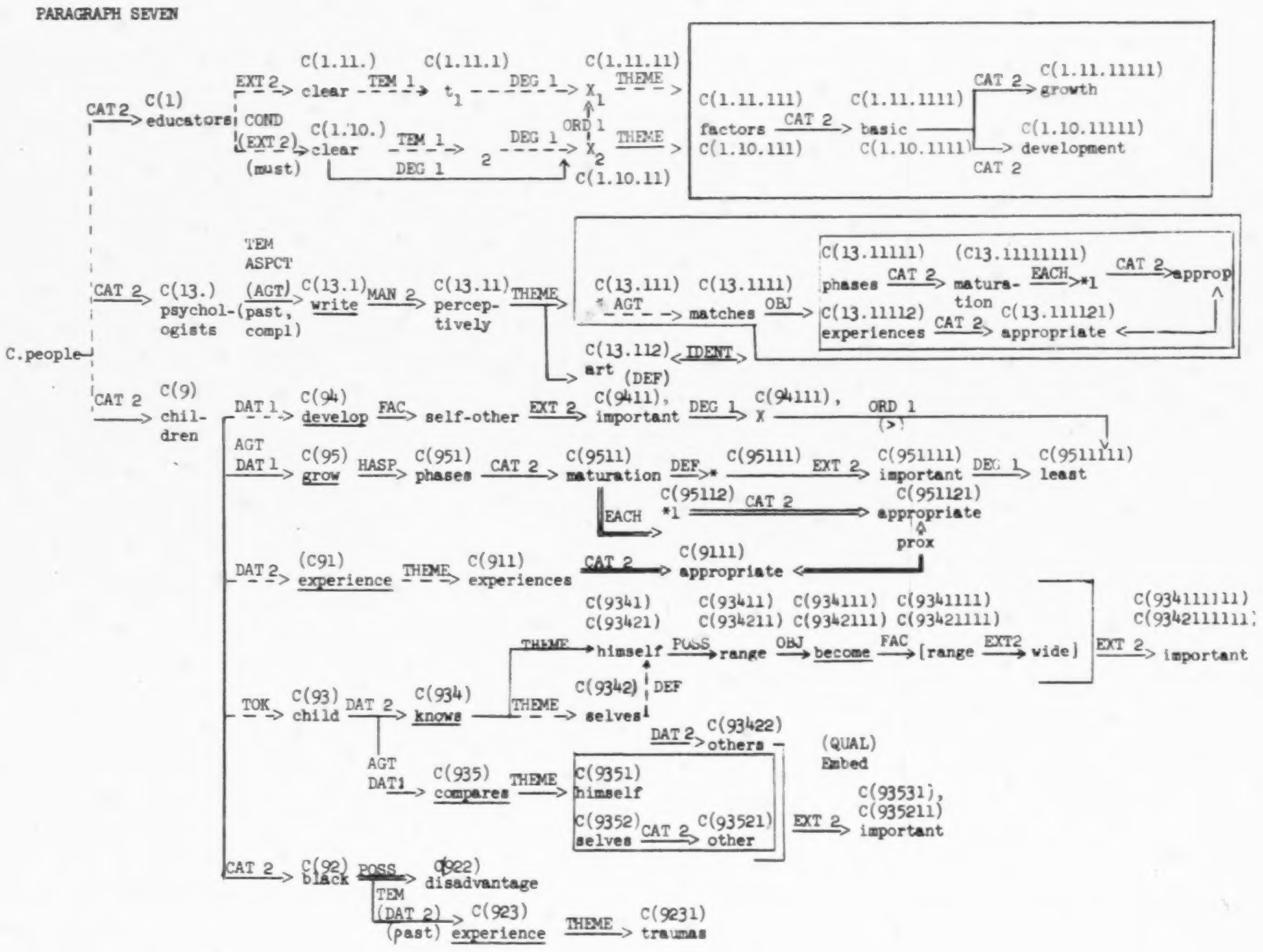

PARAGRAPH SEVEN
C.people
CAT 2
C(1) educators
EXT 2
C(1.11.) clear
TEM 1
C(1.11.1) t1
DEG 1
C(1.11.11) X1
THEME
COND (EXT 2) (must)
C(1.10.) clear
TEM 1
2
DEG 1
ORD 1
X2
C(1.10.11)
C(1.11.111) factors
C(1.10.111)
C(1.11.1111) basic
C(1.10.1111)
C(1.11.11111) growth
C(1.10.11111) development
C(13.) psychologists
TEM ASPCT
(AGT) (past, compl)
C(13.1) write
MAN 2
C(13.11) perceptively
C(13.111) * AGT
C(13.1111) matches
OBJ
C(13.11111) phases
(C13.1111111) maturation
EACH
*1
approp
C(13.11112) experiences
C(13.111121) appropriate
C(13.112) art (DEF)
IDENT
C(9) children
DAT 1
C(94) develop
FAC
self-other
C(9411), important
C(94111), X
ORD 1 (>)
AGT DAT 1
C(95) grow
HASP
C(951) phases
C(9511) maturation
DEF
*
C(95111)
C(951111) important
C(9511111) least
EACH
C(95112) *1
C(951121) appropriate
prox
DAT 2
(C91) experience
C(911) experiences
C(9111) appropriate
TOK
C(93) child
C(934) knows
C(9341) C(93421) himself
POSS
C(93411) C(934211) range
C(934111) C(9342111) become
C(9341111) C(93421111) [range
EXT2
wide]
C(934111111) C(934211111) important
C(9342) selves
DEF
C(93422) others
(QUAL) Embed
AGT DAT1
C(935) compares
C(9351) himself
C(9352) selves
C(93521) other
C(93531), C(935211) important
C(92) black
POSS
C(922) disadvantage
TEM (DAT 2) (past)
C(923) experience
C(9231) traumas

Figure 9.9(b)

Semantic and Logical Structure Graphs for Essay on School Desegregation, paragraph 7

PARAGRAPH SEVEN

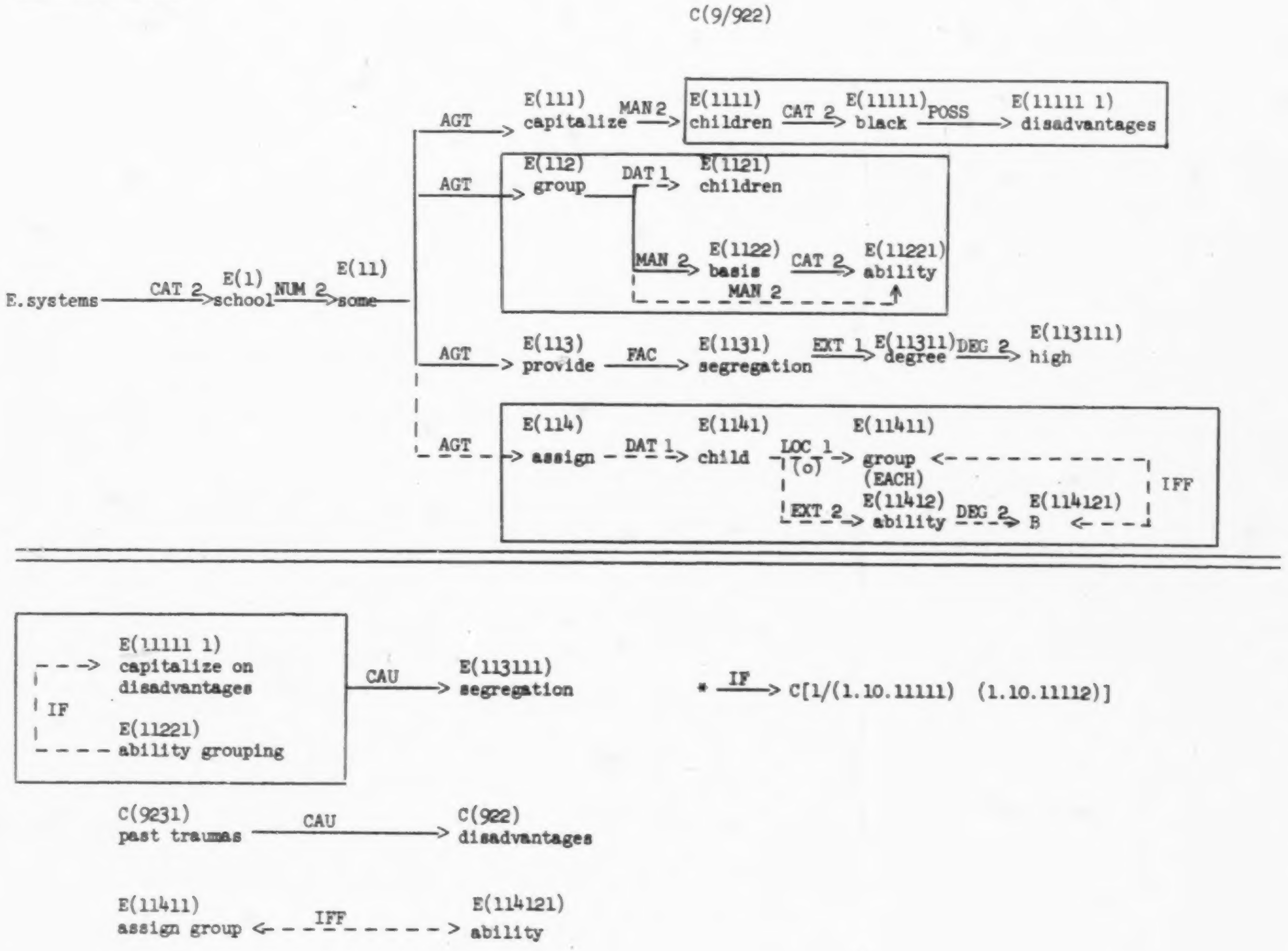

C(9/922)
E.systems
CAT 2
E(1) school
NUM 2
E(11) some
AGT
E(111) capitalize
MAN 2
E(1111) children
CAT 2
E(11111) black
POSS
E(11111 1) disadvantages
AGT
E(112) group
DAT 1
E(1121) children
MAN 2
E(1122) basis
CAT 2
E(11221) ability
MAN 2
AGT
E(113) provide
FAC
E(1131) segregation
EXT 1
E(11311) degree
DEG 2
E(113111) high
AGT
E(114) assign
DAT 1
E(1141) child
LOC 1
(o)
E(11411) group (EACH)
EXT 2
E(11412) ability
DEG 2
E(114121) B
IFF
E(11111 1) capitalize on disadvantages
IF
E(11221) ability grouping
CAU
E(113111) segregation
* IF C[1/(1.10.11111) (1.10.11112)]
C(9231) past traumas
CAU
C(922) disadvantages
E(11411) assign group
IFF
E(114121) ability

Figure 9.10(a)

Semantic Structure Graph for Essay on School Desegregation, paragraph 8

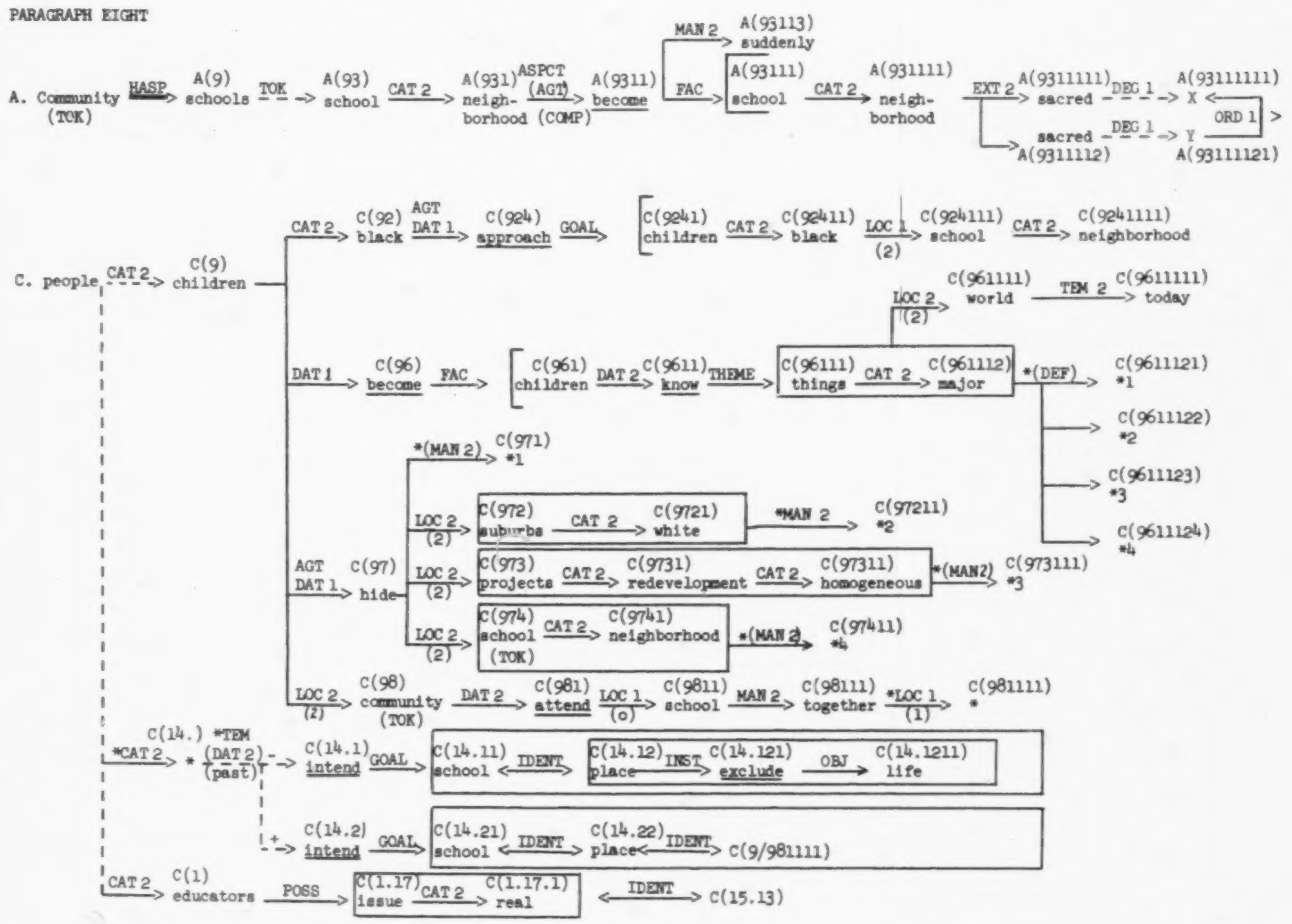
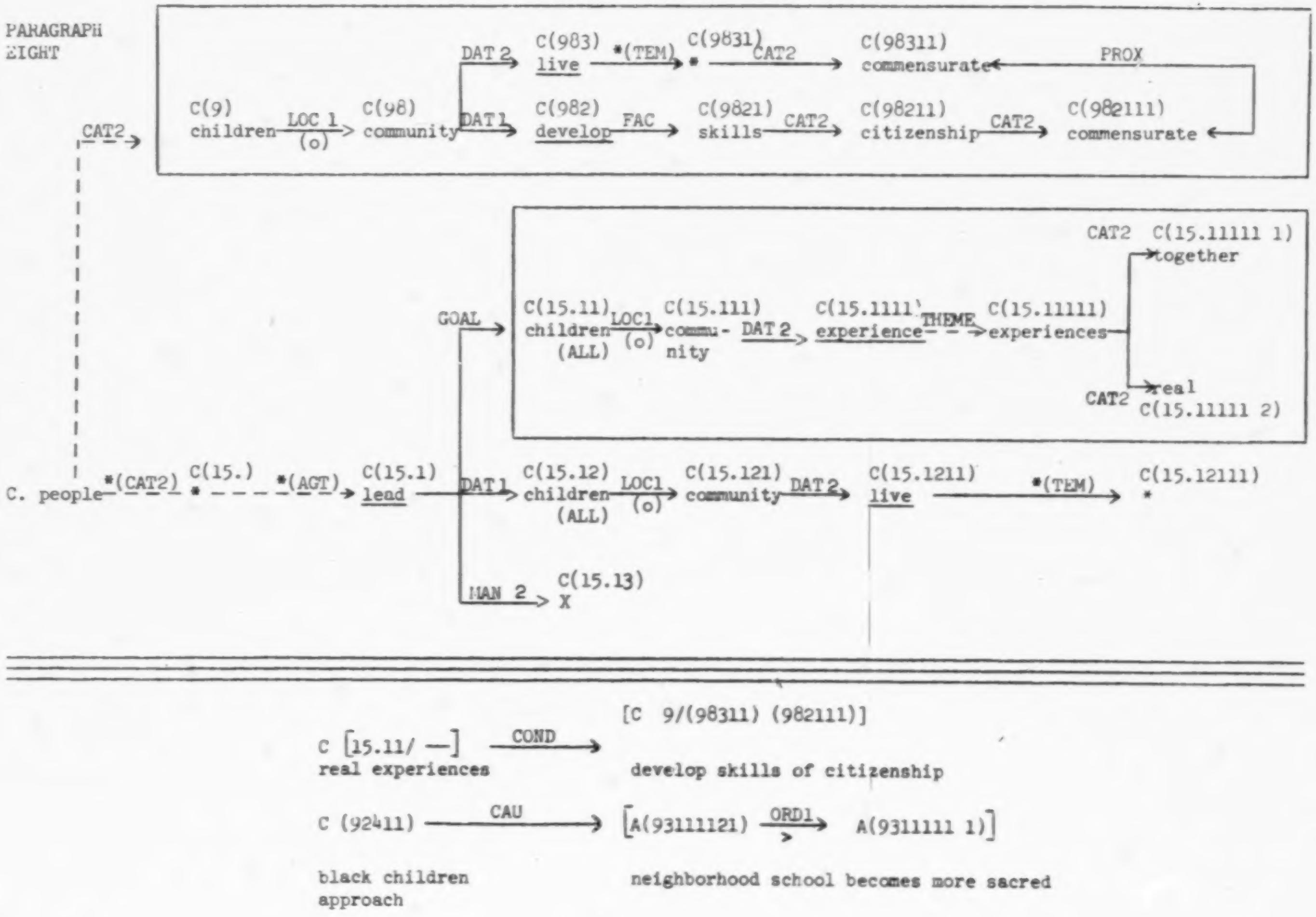

PARAGRAPH EIGHT
A. Community (TOK)
HASP
A(9) schools
TOK
A(93) school
CAT 2
A(931) neigh-borhood
ASPCT (AGT) (COMP)
A(9311) become
MAN 2
A(93113) suddenly
FAC
A(93111) school
CAT 2
A(931111) neigh-borhood
EXT 2
A(9311111) sacred
DEG 1
A(93111111) X
ORD 1
sacred A(9311112)
DEG 1
Y A(93111121)
C. people
CAT 2
C(9) children
CAT 2
C(92) black
AGT DAT 1
C(924) approach
GOAL
C(9241) children
CAT 2
C(92411) black
LOC 1 (2)
C(924111) school
CAT 2
C(9241111) neighborhood
DAT 1
C(96) become
FAC
C(961) children
DAT 2
C(9611) know
THEME
C(96111) things
CAT 2
C(961112) major
LOC 2 (2)
C(961111) world
TEM 2
C(9611111) today
*(DEF)
C(9611121) *1
C(9611122) *2
C(9611123) *3
C(9611124) *4
AGT DAT 1
C(97) hide
*(MAN 2)
C(971) *1
LOC 2 (2)
C(972) suburbs
CAT 2
C(9721) white
*MAN 2
C(97211) *2
LOC 2 (2)
C(973) projects
CAT 2
C(9731) redevelopment
CAT 2
C(97311) homogeneous
*(MAN2)
C(973111) *3
LOC 2 (2)
C(974) school (TOK)
CAT 2
C(9741) neighborhood
*(MAN 2)
C(97411) *4
LOC 2 (2)
C(98) community (TOK)
DAT 2
C(981) attend
LOC 1 (o)
C(9811) school
MAN 2
C(98111) together
*LOC 1 (1)
C(981111) *
*CAT 2
C(14.) *TEM (DAT 2) (past)
C(14.1) intend
GOAL
C(14.11) school
IDENT
C(14.12) place
INST
C(14.121) exclude
OBJ
C(14.1211) life
+
C(14.2) intend
GOAL
C(14.21) school
IDENT
C(14.22) place
IDENT
C(9/981111)
CAT 2
C(1) educators
POSS
C(1.17) issue
CAT 2
C(1.17.1) real
IDENT
C(15.13)

Figure 9.10(b)

Semantic and Logical Structure Graphs for Essay on School Desegregation, paragraph 8


PARAGRAPH EIGHT
CAT2
C(9) children
LOC 1 (o)
C(98) community
DAT 2
C(983) live
*(TEM)
C(9831) *
CAT2
C(98311) commensurate
PROX
DAT1
C(982) develop
FAC
C(9821) skills
CAT2
C(98211) citizenship
CAT2
C(982111) commensurate
GOAL
C(15.11) children (ALL)
LOC1 (o)
C(15.111) commu- nity
DAT 2
C(15.1111) experience
THEME
C(15.11111) experiences
CAT2
C(15.11111 1) together
CAT2
real C(15.11111 2)
C. people
*(CAT2)
C(15.) *
*(AGT)
C(15.1) lead
DAT1
C(15.12) children (ALL)
LOC1 (o)
C(15.121) community
DAT2
C(15.1211) live
*(TEM)
C(15.12111) *
MAN 2
C(15.13) X
C [15.11/ —]
real experiences
COND
[C 9/(98311) (982111)]
develop skills of citizenship
C (92411)
black children approach
CAU
[A(93111121)
ORD1 >
A(9311111 1)]
neighborhood school becomes more sacred

CHAPTER 10

REPRESENTING LOGICO-SEMANTIC INFORMATION ACQUIRED FROM A DISCOURSE

10.1 General Considerations

The purpose of this final chapter is to describe the application of the semantic model presented in the previous chapter to the base comprehension task. Recall that the base comprehension task involves presenting one or more discourses to a subject and asking the subject to reconstruct that knowledge which he has acquired from the presented texts (when a presented text can contain structured deletions from its semantic structure). This task is actually much more general than it may appear to be at first glance. For example, probe retrieval, verification, and question answering tasks may be analyzed as consisting of two texts, the text containing the target semantic information as the first text, and the probe, to-be-verified sentence, or question as the second; and structural relations between the two texts can be represented within a single logico-semantic structural model. As a second example, many problem solving tasks require not only comprehension of the linguistic input which presents the problem, but also that the subject generate specified outcomes from the presented information. Such tasks may be conceived of as requiring a series of formal operations which result in a logico-semantic structural link between one semantic structure, the initial state, and another, the goal. Thus, it may often be possible to represent the structural information constituting the problem and problem solution within a single structural model. In any of these variations of the base comprehension task, problems of logico-semantic analysis of discourse occur both in representing that logico-semantic information which is (perhaps incompletely or imperfectly) coded in a discourse presented to a subject, and in measuring semantic information which is linguistically coded in the verbal protocols which constitute the subjects' performance.

The procedures discussed in Chapter 9 provide a means for generating a semantic model which represents the "structural meaning" of an input passage which is represented (for scoring purposes) in the form of two directed graphs: one representing the semantic structure and one representing the logical structure (see the example in Chapter 9). The scoring problem is, given this model, to measure correspondences between the "meanings" represented by these graph-structures and the "meanings" conveyed by a subject's verbal reconstruction of the input. The scoring method which was developed involves two procedures: (1) a procedure for scoring reproduced or transformed semantic elements by "template-matching" to the structural model of the input, and (2) a procedure for scoring subject-generated semantic elements which do not represent reproduced or transformed input elements. To the extent that the definitions of the elements of the structural model of Chapter 9 are explicit and that the rules by which they combine in the analysis of a specific text are clear, the principal scoring problems which remain involve the use of interpretive rules whereby a semantic structure is generated from surface expressions and lexical substitutions. Since there is in general one surface expression in the paraphrase set for a given semantic structure which is most simply related to the underlying semantic structure (i.e. that surface expression which can be generated from the semantic structure by the simplest rules of expression), the simplest approach to the problem of generating a semantic structure for a subject's protocol appears to be to paraphrase its constituent sentences in such a way that the semantic interpretation is obvious. As experience is acquired in scoring, it will be found that this basic paraphrase step will become unnecessary, except for analyzing difficult portions of a passage. It is hoped that in the future, at least a part of the scoring procedure can be automated. What would be required is a computer program which would be capable of parsing and semantically interpreting (possibly pre-edited) English sentences. Thus the next step ought to be to adopt a surface grammar and develop a set of rules of expression which are capable of mapping from surface expressions to semantic structures. At present, the scoring procedures require that the scorer know the semantic model, be able to generate basic sentence paraphrases, and be able to generate the semantic representation for the paraphrase. As will be seen in the section which follows, the scorer's task may be simplified when the material which is scored consists of reproduced or transformed semantic information which is represented in the structural model of the input discourse. It may also be possible to simplify the task of scoring subject-generated structural elements, for example, by incorporating frequently occurring subject-generated information into the semantic model of the input, by providing the scorer with a dictionary of verbs which are likely to occur, a dictionary which contains a structural representation of the "case frame" for each verb, and by providing the scorer with a list of acceptable lexical substitutions for each lexical element of the input structure.

The second and subsequent parts of this chapter describe certain conventions which were developed for scoring and representing reproduced and subject-generated structural elements in subjects' protocols. Dealt with first are methods for scoring reproduced structural elements by "template-matching," including such topics as criteria for paraphrasing, fitting, scoring transformations of input structures, and marking the semantic and logical structure graphs which are used as scoring sheets. Second, methods for scoring subject-generated structural elements are discussed including problems of paraphrasing, fitting subject-generated elements to the structural model of the input, the logical (inferential) status of subject-generated relations, and procedures for listing scored subject-generated elements. To illustrate the scoring procedures, a portion of a scored protocol obtained for the desegregation passage is presented and analyzed in each section. The final section is concerned with describing a method for the quantitative analysis of scored protocols which can enable one to test semantic-structural hypotheses, and with indicating certain directions in which research on comprehension and semantic memory may go using the base comprehension task.

10.2 Scoring Reproduced Structural Elements

The reproduced structure consists of those parts of a subject's recall protocol which are either paraphrases of portions of an input discourse or transformed paraphrases of portions of an input. Thus the reproduced structure either has a logico-semantic structure identical to a part of the graph-structure of the input, or it may be transformed into an input structure by: (1) applying one of the operators defined in section 9.4, (2) by modifying a quantitative attribute (viz. EXT, LOC, TEM, DEG, NUM, MAN EXT), or (3) by a mode shift (change of type of a relation (e.g. IF ⟶ COND). In practice, scoring reproduced structural elements is relatively easy: the reproduced structure is scored directly on a copy of the graph representation of the input discourse. On these scoring sheets each reproduced concept, relation, or proposition is marked with a number indicating the serial position of the sentence in the protocol. Any relation which has been transformed by a subject by application or alteration of one or more of the seven operators is marked as so transformed. Scoring the reproduced structure involves principally a process of paraphrasing a protocol to fit it to the structural model of the input text. With some experience, it becomes possible to fit directly (without the paraphrase step). The principal purpose of the paraphrase step is to facilitate identifying the graph-structure and matching the structure to the graph-structure of the input text. To illustrate the procedures for scoring the reproduced structure, a portion of an actual recall protocol obtained from the desegregation passage is presented in Table 10.1, just as it appears in the computer listing (see the Appendix for a description of editing procedures and conventions for punching a protocol). This passage was selected because it consists mostly of reproduced or transformed structural elements. Paraphrases of the six sentences follow and elements of the semantic structure which correspond to each segment of the paraphrased text are identified immediately below the corresponding segment of the paraphrase. Notice that in the paraphrases pronouns are replaced with their antecedents, embedded clauses are enclosed in parentheses, words marking logical (intersentential) connectives are enclosed in square brackets, and certain lexical substitutions are made. We have been adopting a lenient criterion for accepting lexical substitutions, taking contextual determiners of the meaning of a lexical item into account. In many research applications or in the development of standardized tests, lists of acceptable substitutes for lexical elements in a text can be provided. The list of basic sentence paraphrases follows:

Table 10.1

Protocol Obtained from Subject 101111: Desegregation Passage, First Six Sentences (trial 4)

1. (BECAUSE THE DOMINANT PEOPLE WITHIN A COMMUNITY ARE COMFORTABLE IN THEIR POWER ROLES (BECAUSE THEIR POSITION IS DEPENDENT UPON EXISTING STRUCTURE (THEY HAVE BUILT ANY ATTACK ON THESE STRUCTURES WILL MEET CONFLICT/

2. THUS A COMMUNITY (CONFRONTS DESEGREGATION WILL MEET CONFLICT FROM THEIR DOMINANT PEOPLE/

3. (SINCE A COMMUNITY USUALLY DOESNT CONFRONT DESEGREGATION THEY ARE NOT PREPARED TO MEET THE CONFLICT AGAINST THEIR CAUSE/

4. THE QUESTION OF (WHO GOES TO SCHOOL WITH WHOM IS NOT DETERMINED BY EDUCATORS/

5. IT IS A POLITICAL MATTER/

6. THIS MEANS (IT IS DECIDED BY POLITICIANS JUDGES AND COUNCILS/

1. [Because] (a community's dominant people (p_1) are comfortable in their power roles)

$$\text{A(11211)}$$

[Because] ((p_1 have status) [depends on] (existing structure))

$$\text{A(113)} \xleftarrow{\text{COND}} \text{A(114111)}^{\text{(INC)}}$$

(p_1 have built existing structure)

$$\text{A(114)} \xrightarrow{\text{FAC}} \text{A(11411114111)}^{\text{(INC)}}$$

(any attack on existing structure) [will cause] conflict

$$\begin{tikzcd}
\text{A(11211)} \arrow[r, "\text{COND}"] & \left[\underline{\text{attack}}\right. \arrow[r, "*\text{(MAN)}"] & * \arrow[r, "\text{EACH}"] & \left.\text{any}\right] \arrow[r, "\text{CAU}"] & \text{conflict} \\
\left[\text{A(114111)} \xrightarrow{\text{COND}} \text{A(113)}\right] \arrow[ur, "\text{COND}"'] & & & &
\end{tikzcd}$$

2. [~~Thus~~] (a community (which confronts desegregation) will experience conflict

$$\text{A(31)} \qquad \text{A(511)}^{\text{(INC)}}$$

(which p_2 produce))

$$\text{A(31)} \xrightarrow{\text{IF}} \text{A(511)}^{\text{(INC)}}$$

3. [Since] (a community usually does not confront desegregation)

$$\text{A} \xrightarrow[\text{(usually)}]{\overset{\text{QUAL}}{\text{-(AGT)}}} \text{confront} \xrightarrow{\text{OBJ}} \text{desegregation} = \text{A(41)}^{\text{(OPER)}}$$

(a community does not prepare (to meet the conflict))

$$\text{A} \overset{\text{-(DAT)}}{\overline{\qquad\quad}} \underset{\text{A(6) (OPER)}}{\underline{\text{prepare}}} \xrightarrow{\text{GOAL}} [\text{community} \xrightarrow{\text{AGT}} \text{meet} \xrightarrow{\text{OBJ}} \underset{\text{(DEF)}}{\text{conflict}}]$$

(the conflict is (* oppose the community's cause))

$$\underset{\text{(DEF)}}{\text{conflict}} \xleftrightarrow{\text{IDENT}} \left[* \xrightarrow{*\text{(AGT)}} \underline{\text{oppose}} \xrightarrow{\text{OBJ}} (\text{community} \xrightarrow{\text{POSS}} \text{cause}) \right]$$

4. (Educators do not decide the question)

$$\text{C(1/131)}$$

(the question is (who goes to school with whom?))

$$\text{C(99, 9.10/C(9911)} \xleftrightarrow{\text{IDENT}} \text{C131}$$

5. (The question is political) = p_2

$$\text{C(9.11/9.11.1)}$$

6. (p_2 [implies] (politicians, judges, and councils decide the question)

C(3/311)
C(4/411)
councils $\xrightarrow{AGT}$ C(31/311)

The letter-number combinations designate substructures in the graph-structure presented in the previous chapter. All elements in the templates which are indicated by the symbols are marked with a number indicating the serial position of the sentence. Note that examples of transformations of operators occur in sentence three. All such transformations are marked on the graph of the input structure which is used as a scoring template. The semantic analysis resulting from these operations results in a rather large set of possible measures. The scoring sheet in Table 10.2 classifies some of the possible scores obtainable from the reproduced structure. The scores in Tables 10.2 (a)-(c) indicate the frequency with which each defined type of semantic or logical relation has been reproduced or transformed, and how it was transformed. Also obtained for the semantic structure is a measure of the size of each complete sub-structure (in number of connected nodes) and the location of each sub-structure in the semantic hierarchy (level of left-most node) (Table 10.3). Since in the logical structure, a propositional node can be reproduced, can contain transformed relations, can contain deletions, or can contain self-generated elements (elaborations), counts of reproduced or transformed logical relations must be classified according to the status of each propositional node. The resulting measures indicated in Table 10.4 summarize the extent to which a person has reproduced and altered the logical structure in his reproduction.

10.3 Scoring Subject-Generated Structural Elements

The analysis of subject-generated structure (i.e., that which is not reproduced or transformed) proceeds in a manner similar to the analysis of an input text. The principal differences have to do with (1) procedures for mapping subject-generated semantic and logical relations into the semantic model of the input text and (2) conventions for representing the coded subject-generated structure in list form. The coding of the subject-generated portions of the sample protocol of Table 10.1 is presented in Table 10.5 to illustrate the scoring procedure. A number of aspects of Table 10.5 require explanation. First, when a concept corresponds to a part of the model of the input, it is denoted by the letter-number combination which designates that part of the semantic model of the input (e.g., A(9/913) denotes "defacto segregated schools"). Second, single concepts which appear in the model of the input are circled. Third, to facilitate representation of embedded constructions, embedded subject-generated propositions are denoted by an "S" followed by a number. Fourth, each triple consisting of two nodes and a connecting semantic or logical relation occupies one line of the list. The left and right "concepts" are listed and

Table 10.2 (a)

REPRODUCED STRUCTURE: SEMANTIC STRUCTURE

	Operators[1]							(Totals)		
CONCEPTS	Rep	-	Q	*	C	?	TA	Rep	Oper	
Nouns	___							___		
Verbs	___							___		
Adj.	___							___		
Adv.	___							___		
(total)								___		
RELATIONS										
Attributive										
1. Ext 1	___	___	___	___	___	___	___	___	___	
Ext 2	___	___	___	___	___	___	___	___	___	
Cat 1	___	___	___	___	___	___	___	___	___	
Cat 2	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	___
2. Ident	___	___	___	___	___	___	___	___	___	___
3. Poss	___	___	___	___	___	___	___	___	___	
Hasp	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	___
Quantifiers										
4. Num 1	___	___	___	___	___	___	___	___	___	
Num 2	___	___	___	___	___	___	___	___	___	
Tok	___	___	___	___	___	___	___	___	___	
Def	___	___	___	___	___	___	___	___	___	
ϕ	___	___	___	___	___	___	___			
Each	___	___	___	___	___	___	___	___	___	
	___	___	___	___	___	___	___	___	___	___
(total)		___	___	___	___	___	___	___	___	___

---

[1] Operators = operator applied or deleted

Table 10.2 (b)

REPRODUCED STRUCTURE: SEMANTIC STRUCTURE

	Operators							(Totals)		
Adverbials	Rep	-	Q	*	C	?	TA	Rep	Oper	
5. Loc 1	___	___	___	___	___	___	___	___	___	
Loc 2	___	___	___	___	___	___	___	___	___	
Tem 1	___	___	___	___	___	___	___	___	___	
Deg 1	___	___	___	___	___	___	___	___	___	
Deg 2	___	___	___	___	___	___	___	___	___	
Man 1	___	___	___	___	___	___	___	___	___	
Man 2	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	___
Active verbs										
6. Agt	___	___	___	___	___	___	___	___	___	
Instl	___	___	___	___	___	___	___	___	___	
Dat 1	___	___	___	___	___	___	___	___	___	
Obj	___	___	___	___	___	___	___	___	___	
Source	___	___	___	___	___	___	___	___	___	
Fac	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	___
Stative verbs										
7. Dat 2	___	___	___	___	___	___	___	___	___	
Obj 2	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	___
8. Theme	___	___	___	___	___	___	___	___	___	
Goal	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	

Table 10.2 (c)

REPRODUCED STRUCTURE: LOGICAL STRUCTURE

		Operators						(Totals)		
Conditionals	Rep	-	Q	*	C	?	TA	Rep	Oper	
9. If	___	___	___	___	___	___	___	___	___	
Iff	___	___	___	___	___	___	___	___	___	
Cond	___	___	___	___	___	___	___	___	___	
Cau	___	___	___	___	___	___	___	___	___	
Dis	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	
Order and Proximity										
10. Equiv	___	___	___	___	___	___	___	___	___	
Ord 1	___	___	___	___	___	___	___	___	___	
Ord 2	___	___	___	___	___	___	___	___	___	
Prox	___	___	___	___	___	___	___	___	___	
P-Ord 1	___	___	___	___	___	___	___	___	___	
P-Ord 2	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	___
11. Or	___	___	___	___	___	___	___	___	___	
And	___	___	___	___	___	___	___	___	___	
(total)		___	___	___	___	___	___	___	___	___
Algebraic										
12. +	___	___	___	___	___	___	___	___	___	
-	___	___	___	___	___	___	___	___	___	
d	___	___	___	___	___	___	___	___	___	
		___	___	___	___	___	___	___	___	___

Table 10.3

REPRODUCED SEMANTIC STRUCTURE

Number of Connected Nodes

Depth	3	4	5	6	7	8	9	10	11	12	13	14
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Table 10.4

REPRODUCED LOGICAL STRUCTURE

Reproduced Logical Relation:

Prop 2

		Rep	Rep Oper	Inc	Inc Oper	Rep Elab	Inc Elab	(Totals)
Prop I	Rep							
	Rep-Oper							
	Inc							
	Inc-Oper							
	Rep-Elab							
	Inc-Elab							
	(totals)							

Transformed Logical Relations:

Prop 2

		Rep	Rep Oper	Inc	Inc Oper	Rep Elab	Inc Elab	(Totals)
Prop 1	Rep							
	Rep-Oper							
	Inc							
	Inc-Oper							
	Rep-Elab							
	Inc-Elab							
	(totals)							

Rep = Reproduced proposition

Oper = Proposition contains oper relations

Inc = Proposition contains deletions

Elab = Proposition contains elaborations

Note: (1) Rep-Oper-Elab goes under Rep-Elab

(2) two entries in each cell: (a) upper left: conditional relations, (b) lower right: other relations defined in the logical structure graph.

Table 10.5

Subject-Generated Structure: Protocol Presented in Table 10.1

Sentence Number		Left Concept	Right Concept	Relation	operators	inferential status
1		A(11211)	S_1	COND		IC
		$A(114111) \xrightarrow{COND} A(113)$	S_1	COND		
	S_1:	attack	t*	MAN	*	
			any	EACH		
			conflict	CAU	TEM(fut)	
2	S_2:	A(111)	produce	AGT	embedded	IC
			conflict	FAC		
		A(511)	S_2	OBJ		
3						
		A(41)	S_3	COND		
	S_3:	$A(6)^{(OPER)}$	S_4	GOAL		
	S_4:	community	meet	AGT		
			conflict	OBJ		
			conflict(DEF)	DEF		
			S_5	IDENT		
	S_5:	oppose	S_6	OBJ		
	S_6:	community	cause	POSS		

consist of either letter-number combinations or a lexical element. The third column contains the label for the type of relation connecting the two concepts. Column four lists any operators applied to the relation and column five codes the inferential status of the subject-generated relation. Every subject-generated relation is either inferred from the closed structure (i.e. is the result of applying rules of inference to the explicitly coded logico-semantic structure), inferred from the open structure (i.e. valid inferences which involve semantic information in addition to that explicitly represented in the text), or elaborative (all others). Note that often a left concept is omitted. When this occurs the left concept is understood to be the right concept of the preceding line. This convention makes it easy to locate chains in the graph-structure.

To further illustrate the scoring procedures which are utilized in analyzing the subject-generated structure, a portion of a second sample protocol is presented in Table 10.6. This sample protocol was obtained after one presentation of the desegregation text and is somewhat atypically difficult to code semantically since it involves a very extensive subject-generated structure. The semantic code for this protocol is presented in Table 10.7. The paraphrase step in the analysis of this protocol has been omitted. The reader may verify the code of Table 10.7 as a way of making apparent the sort of judgments that are required in scoring the subject-generated structure.

10.4 Discussion

In Chapter 2, two sorts of questions involving invariances which are of interest for a theory of natural language comprehension were identified: questions concerning structural invariance: the extent to which the structural characteristics of semantic information acquired from a discourse are fixed or invariant, and process invariance: the extent to which the sequence of processing operations which generate this information are fixed or invariant. Both kinds of invariance can be considered with respect to discourse characteristics (surface and semantic), characteristics of discourse contexts, and other conditions (such as temporal conditions and repeated exposures to a text). The strategy which was adopted in the present research was to attempt to infer characteristics of discourse processing from observations of frequencies of occurrence of particular classes of semantic response in subjects' written reconstructions of knowledge acquired from a discourse. The focus in the present research has been on process invariance. Process invariance was investigated by examining effects of contextual conditions on the relative frequencies of particular classes of responses (Chapter 5). It was also found that by studying the statistical growth properties of these frequency measures, it was possible to make inferences concerning the temporal locus and role of particular processing operations in the acquisition of knowledge from discourse (Chapter 6).

Table 10.6

Protocol Obtained from Subject 101011:

Desegregation Passage, First Six Sentences

1. THE QUESTION IS DEFACTO SEGREGATED SCHOOLS AND THEIR DESEGREGATION
2. EVERY POLITICAL ENTITY EVEN THE COMMUNITY IS CONTROLLED BY A LEADING GROUP WITH ESTABLISHED POWER
3. THIS ESTABLISHED POWER GROUP SEEKS TO PROTECT ITS POSITION AND WILL BE UNLIKELY TO AGREE TO ANY MAJOR CHANGE IN THE COMMUNITY WITHOUT MUCH RESISTANCE
4. INITIAL DECISIONS MADE CONCERNING SEGREGATED SCHOOL SYSTEMS ARE GOING TO BE POLITICAL DECISIONS THE OUTCOME OF STRUGGLE AMONG POWER GROUPS AND LEGAL AND JUDICIAL ARGUMENTS
5. EDUCATORS MUST LET THEIR INFLUENCE BE FELT IN THESE INITIAL POLITICAL DECISIONS
6. THIS CAN BEST BE DONE BY GAINING AN UNDERSTANDING OF THE COMMUNITY AND ACTING WITH CONSENT OF THE AUTHORITY OF THE COMMUNITY

Table 10.7

SEMANTIC CODING: SUBJECT-GENERATED STRUCTURE

Subject #: 1-010-1-1 #1

Sentence number	Left concept[1]	Right concept	relations	operators	inferential status[2]
1					
	question(def)	S1	IDENT		IC
S1:	A(9/913)	S2	AND		IC
S2:	desegregate	A(9/913)	OBJ		IC
2					
	group	power	POSS		IC
S4:		established	EXT		IC
		dominate	AGT		IC
	S4	control	AGT		E
		entity	DAT1		E
S3:		political	CAT2		E
		every	EACH		E
	S3	community	TOK		IO
3					
	S4	seek	AGT		E
		S5	GOAL		
	S4	protect	AGT		
S5:		position	OBJ1		
	S4	position	POSS		
	S4	agree	AGT	-TEM(fut)QUAL(likely)	
		change	OBJ1		
		major	CAT2		
		any	EACH		
		community	LOC1		
	agree	resistance	MAN2	-	
		much	DEG2		

---

1. When a left concept is omitted, it is understood to be the right concept of the preceding line.

2. IC = inferred from the "closed structure," IO = inferred from the "open structure" (involves semantic information not included in the text), E = elaborated.

Table 10.7 (cont'd)

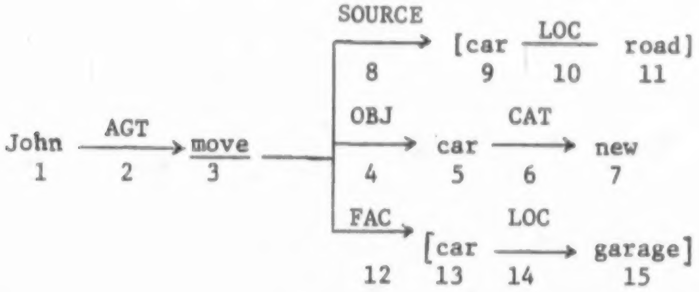
Subject #: 1-010-1-1 #1

4							
			decide	decisions	FAC		E
		S61		initial	CAT2		
			decide	systems	THEME		
	S10			A(9/91)	CAT2		
				political	CAT2	TEM(fut)	
			S6	S10	CAU		
		S6:	S7	S8	AND		
		S7:	groups	power	CAT2		
				struggle	AGT		
		S8:	arguments	legal	CAT2		
			arguments	judicial	CAT2		
5							
		S92	educators	let	AGT	COND(must)	E
				S9	GOAL		
		S9:	feel	influence	OBJ1		
			educators	influence	POSS		
				decisions	MAN2		
				political	CAT2		
				initial	CAT2		
			*	S92	IF	*	
6							
		S91	educators	let	AGT		
				S9	GOAL		
	S10		become	understand	FAC		
				community	THEME		
		S12:	act	S13	MAN2		
		S13:	A(8)	consents	AGT		
		S11:	S10	S12	AND		
			S91	S11	MAN2	QUAL(can)	
				good	EXT2		
				*1	DEG1	*	
				*2	ORD1	* *	
				*2(EACH)	EACH	* *	

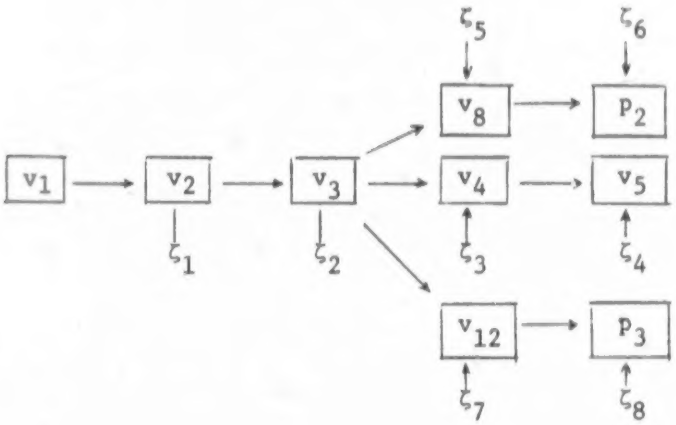
It is also possible to investigate in a similar manner hypotheses concerning structural characteristics of semantic information acquired from a discourse and concerning the structural invariance of acquired semantic information. What is required to permit qualitative investigation of structural hypotheses is a connection between the order properties of the semantic information represented in an input discourse and the order in which information is acquired from the discourse. An assumption which can make this connection is that the order of acquisition of structural elements is related to the form in which the elements are represented in long-term memory, i.e. to the network of structural relations connecting the elements. As an example of the sorts of structural hypotheses which can be considered and the method by which they can be investigated, consider the following sentence:

"John moved the new car from the road to the garage."

The semantic structure for this sentence is (simplifying somewhat):



The numbers are used to designate specific elements (concepts or relations) which are defined in the semantic structure graph. The response vector $\underline{v}' = (v_1, \ldots, v_{15})$ can be defined containing as elements the random variables v_i such that $v_i = 1$ if a semantic element i is present in a subject's protocol and $v_i = 0$ otherwise. If a discourse contains repeated instances of the above semantic structure, then response vectors may be pooled over instances yielding a score vector $\underline{y}' = (y_1, \ldots, y_{15})$ which may be treated as a continuous random vector which has the multinomial distribution with mean vector $\underline{\mu}$ covariance matrix Σ. Linear structural models expressing assumptions concerning the semantic structure may then be fit to this covariance matrix.[1] To simplify the example a bit more, let $p_2 = v_9 + v_{10} + v_{11}$ (corresponding to the locative proposition "the car is in the road") and let $p_3 = v_{13} + v_{14} + v_{15}$ (corresponding to "the car is in the garage"). Then the structural model in the following diagram might be proposed to account for dependencies in the order of acquisition of the semantic elements corresponding to the scores $v_1, \ldots, v_5, v_8, v_{12}, p_2$, and p_3:



The arrows from v_1 to v_2 and from ζ_1 to v_2 indicate that v_2 is derived from v_1 and ζ_1 by the linear equation $v_2 = a_1v_1 + \zeta_1$ where a_1 is a regression weight and ζ_1 is a random variable independent of v_1. The above diagram may be represented by the following system of linear equations:

$$v_2 = a_1v_1 + \zeta_1 \qquad v_4 = a_3v_3 + \zeta_3$$

$$v_3 = a_2v_2 + \zeta_2 \qquad v_5 = a_4v_4 + \zeta_4$$

$$v_8 = a_5v_3 + \zeta_5 \qquad v_{12} = a_7v_3 + \zeta_7$$

$$p_2 = a_6v_8 + \zeta_6 \qquad p_3 = a_8v_{12} + \zeta_8$$

which, in matrix form is

$$\underset{B}{\begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ -a_2 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -a_3 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & -a_4 & 1 & 0 & 0 & 0 & 0 \\ 0 & -a_5 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & -a_6 & 1 & 0 & 0 \\ 0 & -a_7 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & -a_8 & 1 \end{bmatrix}} \underset{\underline{x}}{\begin{bmatrix} v_2 \\ v_3 \\ v_4 \\ v_5 \\ v_8 \\ p_2 \\ v_{12} \\ p_3 \end{bmatrix}} \underset{=}{=} \underset{\Gamma\ \underline{z}}{\begin{bmatrix} a_1 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \\ 0 \end{bmatrix} (v_1)} \underset{+}{+} \underset{\underline{\zeta}}{\begin{bmatrix} \zeta_1 \\ \zeta_2 \\ \zeta_3 \\ \zeta_4 \\ \zeta_5 \\ \zeta_6 \\ \zeta_7 \\ \zeta_8 \end{bmatrix}}$$

defining a linear structural model. In general the coefficient matrices B and Γ are (mxm) and (mxn) respectively. The coefficient matrix B must be nonsingular, and it is assumed that the ζ_i's are mutually independent and that the ζ_i's are independent of $\underline{s}$ and $\underline{z}$. The general model also allows that x and z can contain errors of measurement. Jöreskog and van Thillo have written a computer program which obtains maximum likelihood estimates of all parameters in any identifiable linear structural model by a series of numerical iterations and computes a chi-square statistic measuring the goodness-of-fit of the model to the data (and permitting a statistical test of the fit of model to data)[2].

Thus (in a manner similar to Chapter 6) by comparing the fits of alternative models it is possible to compare the ability of alternative semantic structural models to account for the observed data. If the above model fits data obtained for the example, it would indicate that one can regard the meaning as acquired in the order agent ⟶ verb followed by source (prior state), object, and factitive result (where the latter three cases are not ordered among themselves). By generating and fitting linear models such as these, it will be possible to answer questions such as: "Does the dominance order specified by the semantic model predict probability of recall?" "Are there substructures in the semantic model which act as unitary factors (structural units) in predicting probability of recall?" "Is the analysis of a sentence 'verb-centered' in that the substructure: verb + 'case frame' (concepts connected to the verb by case relations + the connecting relations), acquired as a structural unit? Are structural units acquired independently? Is the semantic structure invariant over transformations of the surface sentences? Do contextual factors affect order of recall?

The logico-semantic structural model and the scoring procedures which have been described in Part II, when used in conjunction with the base comprehension task, appear to provide a very generally applicable research tool for studying the acquisition of semantic knowledge from natural-language discourse. Directions for future research employing the base comprehension task which appear to be particularly promising are: studies of the effects of surface and semantic properties of discourse on semantic information acquired from the discourse, studies of effects of semantic information acquired prior to the presentation of a discourse on the acquisition of new information, additional studies of contextual determiners of discourse processing, and extensions of the research to developmental studies of processes of discourse comprehension and semantic memory. On the basis of the results obtained in the present research, there appears to be substantial evidence which is consistent with a view of discourse comprehension as a complex series of processing operations whereby a listener attempts to infer that conceptual and relational information which a speaker is attempting to communicate, from surface utterances which incompletely and fallibly represent that information. If such a conception of discourse processing is valid, then there is good reason to expect that substantial developmental changes occur well after the initial period of language acquisition (during which most grammatical knowledge is acquired) has been completed, changes in the sequence of processing operations which enable a listener to acquire knowledge from discourse.

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APPENDIX A

SCORING MANUAL FOR RECALL PROTOCOLS USED IN PART I

I. Editing, Coding, and Linguistic Scoring Procedures

1. Editing of Protocols for Computer Counts

Read through each trial of the protocol, correct spelling where it is necessary for understanding. Mark off all independent clauses with a slash (/). The slash should precede the conjunction. Mark the beginning of all subordinate (dependent) clauses with an open parenthesis.

An independent clause may be the main clause in a complex sentence (a sentence composed of two or more clauses); one of several main clauses which are independent in the sense that they could stand alone as a sentence, but the subject has joined them to another clause with a conjunction (usually "and" or "but"); or a simple sentence. See example below.

See p. 47 of ABC of English Usage for a definition of a subordinate clause. Elliptical constructions and constructions using gerunds and participles will give the scorer the most trouble. Use the original passage as a guide--this has been marked for clauses.

EXAMPLE:

Their chief opposition came from the ranchers (who said (that (if the farms grew there would be less land to raise cattle on (and Circle Island would not be able to keep up with its imports/ and they also argued (that more goods would not help (because the two countries (that traded with Newhampton and New Beaton did not need farm goods/ They brought the issue to a vote (with the ranchers voting aginst the canal/ Everyone else voted for it/

A Fragment is to be treated as an independent clause, but asides are to be deleted.

EXAMPLE: There were two, maybe three/

Punctuation, except for the slashes and parentheses, are to be deleted.

EXAMPLE: The farmers can~~'~~t export anything (because the farmers~~'~~land is small~~,~~the farmers raise only enough for their family/

2. Coding of Edited Protocols

Punch cards, beginning the protocol with card column 1. Punch the entire protocol as the scorer has corrected it. The only punctuation to be typed in is as follows:

/	marks end of independent clause
(	marks off subordinate clauses

$	if a word must be divided because you have punched to the end of a card, be sure to leave last column for $, then continue with the remainder of the word in column 1 of the next card.
*	marks end of trial 1
**	marks end of trial 2
***	marks end of trial 3
****	marks end of trial 4
*****	marks end of delayed recall trial. When you have punched an entire trial, begin next trial with a new card.

Header Cards:

These are subject identification cards. One card is to be punched for each subject and should precede the protocol cards for that subject.

CARD COLUMNS

1	2-5	6	7-8	9	10	11-12
(Group)	subject number	sex	age	class	English 1st Lang.?	Age learned Eng. (if col. 10 is Yes, leave blank)
1=A 2=B 3=C		1=M 2=F		1=F 2=S 3=J 4=S 5=G	1=No 2=Yes	

3. Identification of Parts of Speech

On the print-out, identify the following parts of speech (write in the symbol for the part of speech above the word to which it corresponds on the print-out):

Symbol	Part of Speech
a	article (the, a, an)
d	adjective
B	adverb (except those classified under j below)
P	pronoun
R	preposition
N	noun
v	verb
c	conjunction (except those classified under J below)
J	causal conjunction, causal prepositions, and conjunctive adverbs that signify a causal relationship between sentences, clauses or phrases. j's* are:

therefore
so
as a result
because
since
consequently
for
due to
as
thus

j
EXAMPLE: We are going now, for we do not wish
to be late. j
There were few rivers; hence a shortage
of water.

*There may be words other than those listed, which function in a causal way.

Section 7 contains a copy of the original passage which has been edited and marked for parts of speech.

The easiest way to accomplish the identification of all parts of speech it to identify as many as possible, leaving small circles above those which you don't know or about which you are not sure. Then check the dictionary and the ABC of English Usage to identify those words with circles above them. Simple verbs only are to be counted. When there is a complex verb, mark it as follows:

p V
he will have gone

p V n R n
he is having pie for dinner

Gerunds and participles are to be counted as verbs when they are used with verbal force but not when they are used in the sense of nouns or adjectives:

d N
dying swan

N V d
swimming is fun

V N V d N
Laughing, John took her hand

Infinitives are to be marked as verbs, as follows:

p V V
They began to run

4. Tallying of Transformations

Tally the passive transformations, negative transformations, and passive plus negative transformations in the protocol.

EXAMPLES:

Passive

The decision was reached to build a canal.
The decision was reached by the senators.

Negative

Water would not flow into the canal.

Passive plus negative

The decision was not made by the senators.

Note: If there is a compound sentence (two or more independent clauses) or a complex sentence (embedded subordinate clauses) count one for each type of clause that occurs. If there is a compound verb, count each verb transformation.

EXAMPLES:

The decision was made/ and the notice was posted/ (Count as two passive reansformations).

The decision (which was not reached in the first meeting was finally made tonight/ (Count as one passive plus negative, and one passive).

The letter was written and mailed on the same day/ (Count as two passives).

5. Tallying of Ambiguities

Check protocol for ambiguities. Ambiguity is defined as double (and therefore doubtful) meaning in a sentence. Mark ambiguities arising from:

1. Incorrect position of a word, phrase, or clause.

   EXAMPLE: Choose the poems from the green book which I told you to read (what does the adjective clause qualify--poems or books?)

2. Confusion of pronouns.

   EXAMPLE: He told him he was selected to play (who was selected--the speaker or person spoken to?)

3. Through double meaning in words themselves.

   EXAMPLE: The sailors liked the port (wine or harbor?)

4. Unclear antecedent.

   EXAMPLE: I like the book and the pen. It is mine.

Do not dwell overly long on this step. Pick out those ambiguities readily apparent in one reading. If the meaning is clear from the context, do not count an ambiguity arising from example 3 (above).

6. Additional Linguistic Scoring Instructions

1. Write your name on print-out.

2. If you find misspelled words (too many or too few letters) that were missed, circle the word in red and put a check mark in right margin by the line on which it appears.

3. If you find dependent or independent clauses which were missed, pencil in the appropriate mark in red where you think it should go and put a check mark in the right margin by the line in which it appears.

4. Parts of speech should be marked with a No. 2 pencil, passives checked in red, negatives checked in blue, and ambiguities circled with a No. 2 pencil. If you have any questions, leave a large check mark in pencil above the word that is questioned, plus a very large question mark on the outside of the print-out to indicated that it is incomplete.

5. Things which denote number may be nouns or adjectives

   e.g.: enough　more
   one　much
   most

6. The following are pronouns:

   all
   some
   other
   none

7. "all the _____": "all" is an adjective.

7. Scored Input Essay

N v R a N R a N
Circle Island is located in the middle of the Atlantic Ocean,
B R N P v a d N R d d N
north of Ronald Island/ It is a flat island with large grass meadows
v N P v d N C d N C j a N
(called pampas/ It has good soil, but few rivers and hence a shortage
R N
of water/

a d N R a N v N C d N
The main occupations on the island are farming and cattle ranching/
B a N R a N v d H v B v
In general, the farms of the island are small, designed mainly to feed
a N C d N a N B H v R a N R
the farmer and his family/ The ranches, less affected by the lack of
N v d B v a N v P R d
water, are large enough to permit the ranchers to export much of their

N P v a d B N v a d
beef. (which is a black angus variety/ In fact, beef is the only
N R a N j a N v B B d
export of the island/ (Since the rachers are much more prosperous
C a N d N v N
(than the farmers, no ranchers are farmers/

a N v B d N ⓧ R a
The island is run democratically/ All issues are decided by a
d N R a N a d d N v a d
majority vote of the islanders/ The actual governing body is a ten-
N v a N d N v a
man senate, (called the Federal Assembly, (whose job is to carry out the
N R a N j a B d N R a N v
will of the majority/ (Since the most desirable trait in a senator is
d N a N v R a d d d
administrative ability, the senate consists of the island's ten best
d N a d d N R N d N
proven administrators--the ten richest men/ For years, all senators
v N
have been ranchers/

B a d N N v a d
Recently, an island scientist, Dr. Carl Oliver, discovered a cheap
N R v d N R d N N v d N
method of converting salt water into fresh water/ He called this method
N j P R a d N v
saline recycling/ As a result, some of the island farmers wanted to
v a N R a N j P v N R a
build a canal across the island (so that they could use water from the
N R v a d d N P v a
canal to cultivate the island's central region, (which is called the
N P R a N v a d N
Queensland District/ Some of the farmers formed a pro-canal association
C B v a d N
and even persuaded a few senators to join/

a d N R a d d v R a N P
The main opposition to the canal idea came from the ranchers, (who
v C C d N v P R d N P
pointed out (that (if new farms deprived them of grazing land, they
ⓥ B v v d N P N v a
would not be able to export sufficient quantities of beef to match the
d N B d N ⓥ B ⓥ v R
island's imports/ Moreover, this deficit could not be made up by
d N j d N v B ⓥ v R N
increased farming (because farm produce is not in demand in New Hampton
C R N P v a N R P N
or in Beatons Island, (which are the countries (with which Circle Island
v P B v C a d N v a
can trade/ They also pointed out (that a large canal would upset the
d d N j P v a N R a
island's ecological balance (because it would be a barrier to the
d d N P v B R a N
several small species (which migrate seasonally across the island
R d d N
through its central region/

a d N v P a
The pro-canal association, (calling themselves the Citizens
N V a N R v a N R a
Development Association, brought the idea of constructing a canal to a
N
vote/

d a N v d a N R a d N
All the islanders voted/ All the members of the pro-canal asso-
a d a N v R N a P
ciation and all the farmers voted for construction/ and everybody else
v R P a N v R N R N
voted against it/ The majority voted in favor of construction/

a N C v C P v B B
The senate, however, decided (that it would be too ecologically
d v a N P v d C d C
dangerous to have a canal (that was more than two feet wide and one
d R v N R d a N a d
foot deep/ (After starting construction on such a canal, the island
N v d N v R P C a N ∅
engineers found (no water would flow into it/ and the project had to be
v P R a N v d j R a N R
abandoned/ Many of the islanders were angry because of the failure of
a d N P v B d C P v
the canal project/ It appeared extremely likely (that there would be
a d N
a civil war/

TRANSFORMATION: Passive 6 (x)

Negatives 3 (✓)

Neg. + Pass. 1

AMBIGUITIES 0

II. Semantic Scoring Procedures

8. Relational Symbols and Semantic Scoring Principles

Procedures for scoring the semantic or ideational content of each subject's protocol are to be described in the following sections. In general, these scoring procedures require an understanding of the relational structure of the "input" text, a structure which is represented diagrammatically in the large chart reproduced in Figures 3.1-3.8. The semantic analysis represented by this chart is based on the fact that declarative sentences express set relations--that is, they express a relation or relations between two or more denoted sets (also called concepts). A relational structure consisting of a network of set relations can be expressed linguistically in more than one way. In order to understand the scoring instructions which follow, it is first necessary to familiarize yourself with a number of diagrammatic symbols used in this chart. Semantic scoring will consist of paraphrasing (if necessary) the sentences in a subject's protocol to make it fit as closely as possible the semantic structure diagrammed in the chart.

Relational Structure

The large chart represents a diagram of the relational structure of the passage which was read to the subjects. Your job is to familiarize yourself with this "map" and then employ it in scoring each subject's written protocol. The following symbols are all used in the map; each symbol is followed by its definition.

1. A phrase denotes a concept or set. A concept may be a thing, event or attribute, e.g., "ranchers," "prosperous," "voted." Note that in most instances a concept appearing in the chart can be itself broken down into concepts and relations. A concept usually corresponds to the semantic subject of an independent (main) clause, a predicate, a location, a comparative construction, or an embedded (relative) clause. FOR SCORING PURPOSES, EACH CONCEPT PRESENTED IN THE CHART IS TO BE TREATED AS A UNITY.

2. A ———> B denotes an explicit relation: any directed relation which is explicitly stated in the original passage. This symbol should be read: "A has property B" where the property may be a state or a role in an action. Relations: (1) specify states such as: location, time, attributes, possession, class membership, degree, and manner, and (2) specify relationships involved in events such as: agency, instrumentality, object affected, person affected, goal of an action, resulting state, and thematic content. These different sorts of relations are not differentiated in the diagram.

3. A <———> B denotes an explicit identity relation: an identity relation which is explicitly stated in the original passage. This symbol should be read "A is identical to B." Concepts linked by an identity relation can be substituted one for the other.

4. A ════> B denotes an explicit conditional relation, a relation which asserts that the truth of one proposition is conditional on the truth of a second proposition which is explicitly stated in the original passage. Read: "A implies B," "A causes B," or "B is conditional upon A." Usually an "if . . . then" cause and effect relationship between two propositions. In the map, conditional relations are drawn connecting the terminal concepts of their respective propositions.

5. A <════> denotes an explicit bi-directional implication, i.e., a bidirectional logical implication which is explicitly stated in the original passage. Read: "A implies and is implied by B."

6. A – – –> denotes an inferred relation, i.e., a relation which, while not stated directly, is necessarily true within the context of the passage.

7. A = = => B denotes an inferred conditional relation, i.e., a conditional relation which, while not stated directly, is necessarily true within the context of the passage.

8. A ===> denotes an inferred bi-directional implication, i.e., a bidirectional implication which is not explicitly stated, but is necessarily true within the context of the passage.

9. └ is occasionally used to enclose elaborative relations, conditional relations, bi-directional implications, or concepts which are not necessarily true (within the context of the passage) but may be added to the essay without contradicting relations or implications stated or implied by the essay. Relations, implications, and bi-directional implications so enclosed are expressed using the dotted symbols (6), (7), and (8), respectively. A few elaborative relations, conditional relations, or concepts are included in the diagram. Many more are possible and likely to occur in subjects' protocols.

10. When a concept or part of a concept appearing on the map is enclosed in parentheses (), then the attributes or actions denoted by the enclosed words are considered to be optional (and not to be scored).

11. Words enclosed in quotation marks on the map are verbatim items embedded in other concepts. The verbatim words do not have to be there. However, the subject must indicate something is there, e.g., North of "Ronald Island"--the of is essential to the concept because it indicates that the subject knows that the location is north of some other place.

    To make certain that you understand the symbols and their use in the map, read through the essay Circle Island once, then read through it again sentence by sentence while, at the same time, locating each concept and set-relation on the map. Make certain that you understand just what words denote each concept and each relation or implication. Also, locate each inferred concept and set relation on the map, and verify that it is in fact inferred (i.e., necessarily true within the context of the essay). Finally, try to think of additional concepts and relations which are examples of inferred and elaborative concepts, relations, and implications and which are not already diagrammed on the map.

The "map" which you have been studying represents a relatively undetailed specification of semantic structural relations present in the input passage entitled Circle Island. A more detailed "map" would further break down the "concepts" into set relations. The problem of scoring semantic or "ideational" features of a subject's written reconstruction of this "input" essay will be treated by referring to the model of the input provided by the map. Scoring procedures will involve separately scoring different logical features of the subjects' protocols in terms of corresponding parts of this model. We have already distinguished between explicit, inferred, and elaborative concepts, and explicit, inferred, and elaborative relations, conditional relations, identities, and bi-directional implications. From the diagrammatic model, the concepts and set-relations expressed in the original passage may be reconstructed. On the scoring sheets, each concept and relation on the map will be identified by a code number which is used in scoring subject's protocols by reference to the map.

The semantic scoring of subjects' protocols involves three steps: verbatim scoring, concept scoring, and relations scoring. In each step, one type of element will be considered. Each element will be scored in terms of the occurrence of certain logically possible transformations which the subject can make on an element of the input. Thus, for example, the concept "affected less by water shortage" may be correctly present in a subject's written protocol, may be incompletely specified by the subject (e.g., effected by water shortage"), may be overspecified by the subject (e.g., "were desperately in need of water"), or may be entirely absent. Each of these cases represents a transformation of input information by the subject.

9. Verbatim Scoring Instructions

Verbatim scoring of a subject's protocol involves first reading the protocol and underlining every item (of a fifteen-item list of verbatim concepts) which occurs in the protocol (see the verbatim scoring sheet which follows this section). Each verbatim concept is scored as either: correct (verbatim criterion, incompletely specified (if a portion of the verbatim concept appears), overspecified (if the verbatim concept occurs together with additional extraneous specification), or absent. Words in parentheses on the scoring sheet are ignored in scoring the verbatim concept.

EXAMPLES: "Dr. Carl Gustave Oliver" : scored A-, overspecified.
"Assembly" : scored A+, incomplete.

If a verbatim concept is both overspecified and incomplete, it is scored as incomplete (e.g., "Rhode Island" : A+, incomplete). If "Pacific" were present in a subject's protocol (and "Atlantic" did not appear), verbatim concept 3. "Atlantic" would not be checked. "Pacific" would be scored later as an additional elaborative concept.

Note the following rules:

1. Phonetic spelling is scored correct.
2. Change in the order of words is allowed.
3. "Feet" can be written as "foot" and vice versa.

In addition to these scores, the sequence number of each verbatim concept in the subject's protocol relative to other verbatim concepts is recorded in an appropriate blank. Total verbatim concepts correct, incomplete, and overspecified are obtained and entered at the bottom of the scoring sheet. Repetitions of verbatim concepts are not counted and repeated verbatim concepts are not scored.

10. Concept Scoring Instructions

General description of scoring procedures

Concept scoring involves underlining and scoring each of a list of concepts which appears in the original passage and which is numbered and diagrammed in the model. The scoring sheets contain a list of these numbered concepts section-by-section.

Explicit, inferred, and elaborative concepts

Every concept appearing in a subject's protocol will be classified as explicit, inferred, or elaborative. A particular concept appearing in a protocol is classified as explicit if it corresponds to a numbered explicit concept on the map. An explicit concept may be scored present and correct, incompletely specified (concept-set not completely delimited, i.e., includes subsets not corresponding to the concept-set of the input), or over-specified (concept-set overly delimited, i.e., represents a subset of the concept-set of the input). Since the last two transformation of an explicit concept may occur, it is often necessary to consider the context (relations involving the concept of the protocol and those of the input passage) in identifying a subject's concept with an explicit concept in the input.

An inferred concept does not correspond to any explicit concept, but does enter into relations with explicit concepts which are necessarily true.

EXAMPLE: "New farms reduce grazing land and result in less beef production." Here, "less beef production" enters into an implication which is necessarily true but does not correspond to any explicit concept. Thus, it is inferred.

Inferred concepts are scored as present only when they are identified in a subject's protocol. Some inferred concepts are listed and diagrammed on the map; many will have to be listed separately.

An elaborative concept is neither explicit nor inferred. Thus, an elaborative concept enters into no relationships which are necessarily true. This "truth test" criterion is used to distinguish between inferred and elaborative concepts. An elaborative concept is to be scored only as present (subject-generated) when it is identified in a subject's protocol. Most elaborative concepts will have to be listed separately.

Procedure for marking print-outs

1. First, underline the concepts on the print-out. It is helpful to underling the verbatim concepts in red and the other concepts in pencil.

2. Number the concepts on the print-out as you number them on the scoring sheet (sequence numbers). This helps you to keep track of the sequencing and in scoring the relations.

3. When it is difficult to decide how to score a concept, circle it and make all your difficult decisions last.

Definitions of scoring categories

1. A (Correct) = Subject's words are identical to or paraphrase those listed for the concept. In the case of verbatim items, the subject's words are the same as the listed concept (phonetic spelling accepted).

2. A+ = (incompletely specified) = Subject's words denote a set which is more general than that specified by the listed concept, i.e., subject has left out words that are essential to the concept and thus has not specified the concept completely. This category to be used for explicit concepts only.

3. A- (over-specification) = Subject's words specify a subset of the set denoted by the listed concept, i.e., subject has added words to the listed concept, such that the meaning of the concept is altered by overspecification in such a way that its relations with other concepts (as given by the map) are no longer all true. This category should be used as little as possible, and only for the explicit concepts.

Scoring Sheet

1. Make a check mark in the appropriate column and write the sequence number (serial position of the first occurrence of a concept in a subject's protocol) in the blank between the concept number and the concept.

2. List additional elaborative and inferred concepts on the last page of the scoring booklet. The rule to follow is: Fit a concept wherever possible to those already listed. When you have finished a trial, go over those elaborative and inferred concepts that you have listed as additional and try to fit them to numbered concepts.

3. For repeated additional elaborative and inferred concepts, make a check mark in the column for serial position, but do not give the repeated concept a sequence number.

Scoring map and passage

It is a good idea to keep a copy of the map and passage before you when you are scoring. These are necessary when judgments must be made in fitting a concept.

Repeated concepts

1. When a concept is repeated, make another check-mark for it in the appropriate column. If a concept is checked in two or more columns (say A and A+) circle the first check mark made, i.e., the check mark that corresponds to the sequence number. When a concept is not renamed but is repeated as a pronoun, do not place a check mark for the pronoun.

2. Do not check verbatim concepts more than once, even if they are repeated.

3. See item No. 3 under Scoring Sheet for repeated additional elaborative and inferred concepts.

Arbitrary semantic decisions

1. When subject uses the article the with generic terms (e.g., the ranchers, the farmers, etc.), or when only the generic term is used (e.g., ranchers, farmers), the following scoring procedures should be followed:

   (a) where the listed concept uses the plus generic term, or just the generic term, any quantification written by the subject should be scored as over-specified (e.g., all farmers, most farmers, some farmers, etc)

   (b) Where the listed concept uses a quantifier (all the farmers, some farmers, etc.) the subject's use of the plus generic term, or just generic term, should be scored as under-specified.

2. Constructions such as "No ranchers are farmers" are to be scored as "ranchers are not farmers."

3. Constructions such as "Only ranchers are senators" are to be scored as follows:

   (a) "No one but ranchers"--inferred concept
   "ranchers"--explicit concept
   "senators"--explicit concept

Pronouns

Pronouns are not scored except in the following case:

1. When the pronoun refers to a previously unscored concept, i.e., its antecedent is a concept which is embedded in another concept such that the antecedent was not previously scored separately but as part of the concept in which it is embedded--e.g., "(a scientist) discovered a desalinzation method. It is called saline recycling." In this example the "it" refers to the desalination method and you should score concepts Nos. 71, 86, and 87.

2. Sometimes a subject will write the following: "Some farmers wanted to build a canal across the island. They formed a pro-canal association." In this case, you should score concepts Nos. 78, 79, 80, 81, and 88, because "they" refers both to the "some farmers" who wanted to build the canal and to the "some farmers" who formed the pro-canal association.

Ambiguities

1. Since we are not checking pronouns, ambiguous pronouns will give the concept scorer no trouble. However, they will give the relations scorer trouble. If the ambiguous pronoun has not already been circled on the print-out and counted by the linguistic scorer, please be sure to circle it in red and change the totals under "ambiguities." Also circle that total in red so the data cards can be changed.

2. Semantic ambiguities will arise when the subject refers to such concepts as "the process" or "that idea" without having previously identified or mentioned a process or idea. When this occurs, fit the concept where you can and check the incomplete (A+) category. In some cases, it may have to be listed as an additional inferred or elaborative concept.

Identities

When a subject replaces a part of a concept with an identity (words replaced are shown on the map as equivalences), the concept should be scored correct.

EXAMPLE: "formed a Citizens Development Association."

Concept No. 81 should be scored correct because "pro-canal association" and "citizens development association" are identities. The only exception is in the case when the identity involved was inferred (not stated explicitly in the original text).

Apposition

When a subject indicates an identity by apposition, a part of a phrase denoting a concept may be scored, e.g., in "discovered desalination method saline recycling," concepts Nos. 71, 86, 87 are scored. This is necessary because when the relations are scored, all three concepts must be scored in order to represent correctly the relations that are mapped between these concepts.

Qualification

If a subject qualifies statements which are not qualified in the passage--using such words as "possibly," "might," "may." etc.--score the concept as correct. Conditional statements of an "if . . .then" nature will be handled in the relations scoring.

Changes in computer listing

If you find it necessary to look up a subject's written protocol and to correct the computer listing of the protocol by adding or deleting words, be sure to indicate on the listing that it has been corrected. This is necessary to indicate that totals on the simple counts and linguistic scoring counts must be corrected.

Scoring decisions

1. When a concept fits both the incomplete and overspecified categories, i.e., something is added and something is left out, check the concept in the incomplete (A+) category.[1]

---

[1] NOTE: Only repeated concepts may be checked in more than one category. When this occurs, be sure to circle the check mark that corresponds to the sequence number, i.e., circle the first check mark that you make.

2. When making a decision regarding the fitting of the concept, the following procedures should be followed:

    a. Decide what the concept is.
    b. Decide what section it is in.
    c. Try to fit it to concepts in that section.
    d. If it seems to fit more than one concept, look at the context, i.e., the other concepts that are related to the concept in question.

3. When you have difficulty deciding if a concept is present as an A- or A+ or if it really should be written in as an additional inferred or elaborative concept, the rule to follow is--fit it if possible to explicit concepts, using the following guide lines for the overspecified category:

    (a) the test for the overspecified category (A-) is: does the overspecification change the meaning of the listed concept in such a way that it is recognizably the same concept, but the set denoted by the listed concept has been made smaller or more specific by the subject? If so, score the listed concept as overspecified (A-). Or is the complete listed concept there plus something additional such that the concept can be scored correct as listed, and the additional words be written as an additional inferred concept or an additional elaborative concept.

    (b) Use the overspecified category and the incomplete category for explicit concepts only.

    (c) Use the overspecified category only where the overspecification is clear to you. If you are in doubt, write the concept out under additional inferred or elaborative concepts and put a question mark by it.

Difficult judgments

1. Write in the subject's words next to the concept on the scoring sheet when a difficult judgment must be made. This is the only writing that must be done except where it is necessary to list additional inferred or elaborative concepts.

2. If, after you have made your judgment, you still have doubts, put a question mark in the column to the extreme left (section column) and someone will double-check that judgment.

3. When trying to decide how to score the subject's words "farmers" or "the farmers" or "most farmers," etc., use the context in which it is used to decide whether to score concept No. 12, concept No. 78, or concept No. 80--e.g., if the subject writes "some farmers are not as prosperous as ranchers," score concept No. 12 as overspecified. If the subject writes "farmers formed a procanal group," score concept No. 80 as incomplete.

Incomplete concepts at the end of a protocol

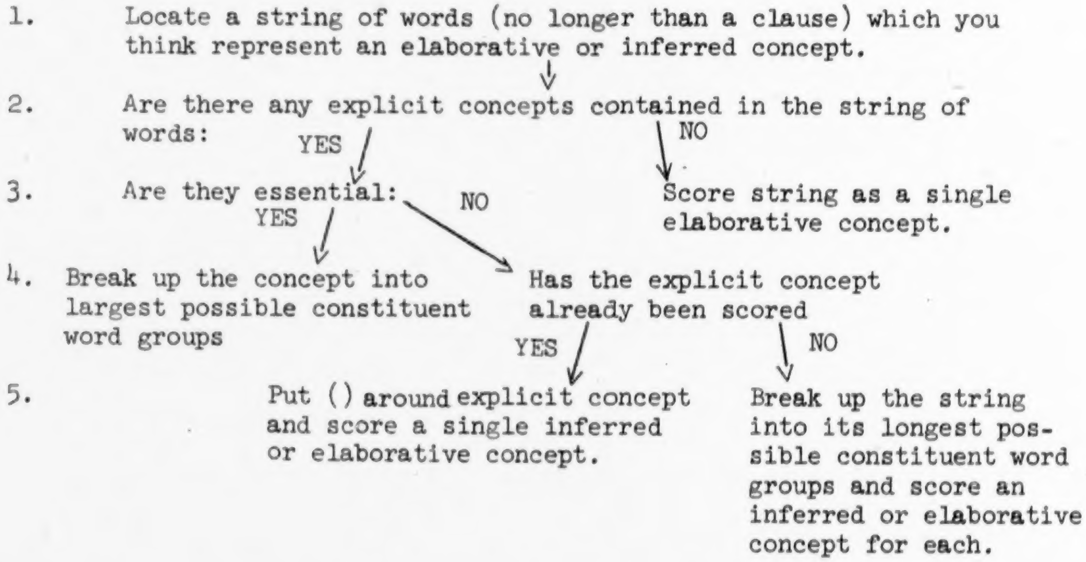
Since subjects were given a time limit in which to write, many subjects had to stop writing in mid-sentence when the time ran out. In scoring these sentence fragments at the end of the protocol, do not score the final concept in the fragment, if that final concept is incomplete. For example, suppose that the final words in a protocol are:

> "Many people were angry and a civil war"
> 141 142

Score only concepts 141 and 142, but do not score the words "a civil war."

Decisions involving subject-generated inferred or elaborative concepts

The sequence of scoring decisions which must be made in deciding whether a string of words which correspond to one or more subject-generated inferred or elaborative concepts should be listed and counted as a single inferred or elaborative concept are summarized in the following flow chart.



1. Locate a string of words (no longer than a clause) which you think represent an elaborative or inferred concept.

2. Are there any explicit concepts contained in the string of words:

3. Are they essential: — Score string as a single elaborative concept.

4. Break up the concept into largest possible constituent word groups — Has the explicit concept already been scored

5. Put () around explicit concept and score a single inferred or elaborative concept. — Break up the string into its longest possible constituent word groups and score an inferred or elaborative concept for each.

Note that a word group can be a noun group, a verb group, a preposition group, an adjective group, or a clause or predicate containing these groups as constituents.

Totals

Counts of the number of explicit concepts present, incompletely specified and overspecified concepts in each section should be made. Counts of inferred and elaborative concepts present in each section should also be made and the results recorded. For totaling repetitions, count the number of repeats in all columns and record this count for each section.

11. Scored Input Essay: Concepts

Circle Island[2] is located in the middle of the Atlantic Ocean[3], north of Ronald Island[4]. It is a flat island[5] with large grass meadows[6] called pampas[7]. It has good soil[8], but few rivers[9] and hence a shortage of water[10].

The main occupations[11] on the island are farming[20] and cattle ranching[25]. In general, the farms[29] of the island are small[30], designed mainly to feed the farmer and his family[33]. The ranches[37], less affected by the lack of water[38], are large enough[39] to permit the ranchers[21] to export[41] much of their beef[42], which is a black angus[47] (variety). In fact, beef[44] is the only export[43] of the island[2]. Since the ranchers[21] are much more prosperous than the farmers[22], no[21] ranchers are farmers[23].

The island[2] is run[48] democratically[49]. All issues[50] are decided by a majority vote (of the islanders)[51]. The (actual) governing body[56] is a ten-man[57] senate[65] called the Federal Assembly[67], whose job is to carry out the will of the majority[65]. Since the most desirable trait[59] in a senator[57] is administrative ability[58], the senate[55] consists of the island's[2] ten best (proven) administrators[66]--the ten richest men[62]. For years, all senators[57] have been ranchers[21].

(Recently), an (island) scientist[69], Dr. Carl Oliver[70], discovered a cheap[74] method of converting salt water into fresh water[71]. He called this method "saline recycling[72]." As a result, some of the island farmers[78] wanted[79] to build a canal across the island[81] so that they could use water from the canal to cultivate (the island's) central region[87], which[84] (is called) the Queensland District[85]. Some of the farmers[80] formed
(= central region) 81
a pro-canal association and (even) persuaded a few senators to join[82].

The main opposition 98 to the canal idea 96 came from the ranchers 21, who pointed out 99 that if new farms 103 deprived them of grazing land 104, they would not be able to export sufficient quantities of beef to match the island's imports 108. Moreover, this deficit could not be made up 111 by increased farming 105 because farm produce 109 is not in demand in "New Hampton" or in "Beatons Island 110," which are the countries with which Circle Island can trade 110. They also pointed out 99 that a large canal 100 would upset the island's ecological balance 102 because it would be a barrier to the several small species which migrate seasonally across the island through its central region. 114"

The pro-canal association 83, calling themselves the Citizens Development Association 120, brought the idea of constructing a canal to a vote. 119

All the islanders 122 voted. 123 All the members of the pro-canal association 126 and all the farmers 125 voted for construction 124, and everybody else 130 voted against it. The majority voted in favor of construction.

The senate 55, however, decided 134 that it would be too ecologically dangerous 140 to have a canal that was more than two feet wide and one foot deep. 135 After starting construction on such a canal 145 the island engineers 136 found no water would flow into it 137, and the project had to be abandoned 138. Many of the islanders 141 were angry 142 because of the failure of the canal project. 134 It appeared extremely likely that there would be a civil war. 143

CONCEPTS SCORING SHEET

Concepts explicit
inferred (preceded by a *)
elaborative (preceded by a **)

Section	A Correct	A+ Inc.	A- Over	Serial Pos.	Concept
1.*	___	___	___	*1.	PHYSICAL DESCRIPTION
___	___	___	___	3.	In the middle of the (Atlantic) Ocean
___	___	___	___	4.	North of "Ronald Island"
___	___	___	___	5.	Is flat
___	___	___	___	6.	Has (large, grass) meadow, grasslands
___	___	___	___	8.	Good soil, fertile, etc.
___	___	___	___	9.	few rivers
___	___	___	___	10.	water shortage, lack of water
2.	___	___	___	11.	MAIN OCCUPATIONS
___	___	___	___	12.	farmers
*	___	___	___	*13.	(Island's) Inhabitants
*	___	___	___	*14.	Not as prosperous as ranchers
*	___	___	___	*15.	Not ranchers
*	___	___	___	*16.	Other occupations
**	___	___	___	**17.	Can't buy land
**	___	___	___	**18.	Not good administrators
**	___	___	___	**19.	Farming not lucrative
___	___	___	___	20.	Farming
___	___	___	___	21.	Ranchers
___	___	___	___	22.	Much more prosperous than farmers
___	___	___	___	23.	Not farmers
*	___	___	___	*24.	others (not ranchers and not farmers)
___	___	___	___	25.	(cattle) ranching
*	___	___	___	*26.	Raise cattle
**	___	___	___	**27.	Rich
**	___	___	___	**36.	Poor

12. Set-Relations Scoring Instructions

Set relations scoring, like the concept scoring, involves scoring a subject's protocol against the diagrammatic model of the original passage. As in the concept scoring, set relation scoring consists of categorizing a set relation in a subject's protocol in terms of transformations on a set relation in the model with which the set relation in the protocol is identified.

Identifying a Relation

A set relation in a subject's protocol is identifiable with a stated set relation in the input passage if the relation appearing in the protocol may be transformed into that in the input passage by one of several possible transformation:

(1) transformation of mode [relation to conditional relation and vice versa]

(2) transformation of direction [for unidirectional relations or conditional relations]

(3) to or from an "identity" [i.e., a unidirectional relation may be made bi-directional or a unidirectional implication may be made bi-directional and vice versa]

(4) combinations of the above

Identification, then, involves finding a set relation on the map which corresponds to a subject's stated set relation, allowing that the subject may have modified the relation by one of these transformations. Since the subject's concepts have already been identified and scored, location of a set relation may be accomplished comparatively easily. If a particular set relation in a subject's protocol involves one or more elaborative concepts, then it may not be identifiable with an explicit relation or one which may be inferred from the context. In this case, the relation is elaborative and is scored only as present (subject-produced) or present and necessarily false (if it contradicts any part of the passage). Elaborative relations may also occur in cases in which both concepts are explicit or inferred.

Definition of Scoring Categories

Each set relation in a subject's protocol consists of two concepts and a connecting relation, A'R'B' (e.g., "Circle Island [A'] is [R'] flat [B']"). Scoring a subject's set relation involves entering the scores of both concepts and then scoring the relation. A subject's set relation A'R'B' may be explicit (if it may be identified with a relation ARB which is stated explicitly in the input essay), inferred (if it is not identifiable with a relation which is stated directly, but is identifiable with a relation which is necessarily true), or elaborative (if it is neither explicit nor inferred).

I. The following Scoring categories apply to explicit set relations:

   A. FOR THE CONCEPTS (A', B'):

      1. Score 1 if concept is correct (i.e., A' = A)

      2. Score 2 if concept is incompletely specified (i.e., A' = A+)

      3. Score 3 if concept is overspecified (i.e., A' = A-)

      [THESE SCORES ARE ENTERED ON THE SCORING SHEET FROM THE CONCEPT SCORES].

   B. FOR THE RELATION (R'):

      1. Score R if relation is correct (i.e., R' = R).

      2. Score M if relation is changed in mode.

      3. Score D if relation is changed in direction.

      4. Score I if relation is changed to or from an identity or bi-directional implication.

      5. Score MD if relation is changed in both mode and direction.

      6. Score MI if relation is changed in both mode and to or from an identity or bi-directional implication

II. The following scoring categories apply to inferred set relations:

   A. FOR THE CONCEPTS (A', B'):

      1. The same as for explicit concepts except that an additional category is possible:

         a. Score S if concept is a subject-produced inferred concept.

   B. FOR THE RELATION (R'):

      1. Score R for every inferred relation present.

III. The following scoring categories apply to elaborative set relations:

   A. FOR CONCEPTS (A' B'):

      1. The same as for concepts under II

   B. FOR RELATION (R'):

      1. Score SC if subject-produced elaborative relation is not necessarily false.

      2. Score SF if subject-produced elaborative relation is necessarily false.

Entering Concept and Relation Scores

As you proceed through a subject's protocol, you will score each set relation as you come to it. First locate a set relation on the map and find the corresponding number on the scoring sheet. Enter the previously obtained concept scores in the columns A' and B' (A' is the first concept, B' is the second). If you are scoring relations and concepts together, you will first carry out the concept scoring, then enter the concept scores on the relation scoring sheet. Having entered the concept scores, determine the type of relation--explicit, inferred, or elaborative (type has already been listed for all numbered relation)--and then determine the appropriate score category for the relations. Finally, enter the code for the appropriate score category on the scoring sheet in the column headed by R'.

Scoring Decisions

1. Locate the set-relation on the map which is identifiable with the subject's set relation under consideration. In making this "identification" decision, several factors are important:

   (a) If either one or both concepts are subject-produced (scored S), no relation will have been previously mapped. In this case, you should list the two concepts in space provided on the scoring sheets. (Use the extra space under the appropriate section of the passage.) If one of the two concepts is mapped, just write down its number.

   (b) If one or both concepts are scored S, the relation is either inferred or elaborative. To make this decision as to the type of relation, decide whether or not the set relation is necessarily true (i.e., is the subject's stated relation inferrable from the context). If you decide yes, then enter an "I" in the column marked "type." Otherwise, enter an "E." This column must not remain blank for any listed set relations.

   (c) Enter the appropriate concept scores for the two concepts. If a concept has been judged subject-produced and listed, an S should be entered. All other concepts should be scored with a 1 (correct), 2 (incompletely specified), or 3 (overspecified).

   (d) If the subject's set relation is explicit, decide what (if any) transformation is necessary to convert the subject's stated relation to the mapped relation. Enter the appropriate scoring code in the column headed R'. Remember, do not read meaning into what a subject has written; score only what he has said explicitly

   (e) If the subject's set relation is elaborative, decide whether or not his relation is contradicted by the passage (i.e., is necessarily false). If you decide that it is necessarily false, score SF in the column labeled R'; otherwise, score SC.

Difficult Scoring Decisions

Two sorts of circumstances can arise which complicate the above scoring decision somewhat. These are:

a. Implications involving compound concepts

b. Implications in which one of the concepts is replaced by a set relation (nested relation)

Rules for scoring each of these cases follow.

Conditional Relations ("Implications") Involving Compound Concepts

Implications may occur in which more than two concepts are involved in the set relation. Three cases can occur:

1. the concept-set on the left may be compound, e.g., A and B $\Longrightarrow$ C.
2. the concept-set on the right may be compound, e.g., A $\Longrightarrow$ B and C.
3. both concept-sets may be compound, e.g., A and B $\Longrightarrow$ C and D

To score implications involving compound concepts, use the following scoring rules:

1. If the protocol indicates that you can break down an implication in which one or both concepts are compound into separate implications, do so and score the separate implications individually.
2. If the protocol does not indicate that the implication can be broken into separate implications, then score each compound concept in the appropriate column (A' or B') by:
   (a) scoring correct if the compound concept-set contains no incomplete or overspecified concepts within the set.
   (b) scoring incompletely specified (A+) if it contains any incomplete concepts.
   (c) scoring overspecified (A-) if it contains any overspecified concepts (A-'s) and no incompletely specified concepts (no A+'s).

When an implication involving compound concepts is scored, indicate on the scoring sheet what concepts make up each compound concept.

Nested Relations

Implications may occur in which one of the concepts is itself a set relation. Consider the following two examples taken from Circle Island.

Example 1. "Since Circle Island^{X} has few rivers^{Y}, there is a lack of water^{Z}."

Generally, we can write this as $[X \longrightarrow Y] \Longrightarrow Z$ [case 1]

Example 2: "Since the Island is a democracy^{Z}, all issues^{X} are decided by a majority vote (of the islanders)^{Y}."

Generally, we can write this as $Z \Longrightarrow [X \longrightarrow Y]$. [case 2]

If a subject's protocol contains a set relation which corresponds to either of these cases or their extensions, the following scoring rules should be followed.

Let $A = X \longrightarrow Y$ and let $A' = X' \longrightarrow Y'$. The implication to be scored is either $A'R'Z'$ or $Z'R'A'$. *Scoring categories* for scoring A' (which is itself a relation or set of relations are:

1) Score "1" (*correct*) when, for example, $A' = A = XRY$, i.e., the set of *relations* and *concepts* which make up A' are all correctly specified by the subject.

2) Score "2" (*incompletely specified*) when, for example, $A' = X'RY'$ and either X' or Y' or both are incompletely specified, i.e., the set of *relations* which make up A' are all correctly specified, but at least one concept is incompletely specified.

3) Score "3" for all other cases, i.e., when any one or more relations are transformed and/or when any one or more concepts are overspecified. This score is also to be used if any elaborative relations occur involving the set of concepts and relations in A' which are necessarily false within the context of the essay.

Note that score category (3) lumps together many possible combinations of subject transformations and elaborations.

4) Score "S" if one (or more) of the concepts of one (or more) of the relations is subject-produced.

Substitution of Identities

Note that in scoring any relation or implication, identities may always be substituted. Thus, "Queensland District" may always be substituted for "Central Region", etc. However, inferred identities are not to be treated as interchangeable.

Additional Scoring Rules

1. *Ambiguous conditionality*. If a subject's protocol indicates a conditional relation, but the concept A' or B' is ambiguous (i.e., it is impossible to determine exactly the concepts and relations that are included in the A' and/or B'), then this implication cannot be scored. In other words, do not score an implication if you cannot determine

the A' and/or B'.

2. Relations involving incomplete concepts at the end of the protocol. Since incomplete concepts at the end of the protocol are not to be scored, this means you will be unable to score any relations involving that incomplete concept.

3. Relations 5.63 and 5.62. The B' for these relations is to be scored in the same way that nested relations are scored. For example, suppose that subject writes:

   "The ranchers pointed out that farms would deprive them
   21 99 103+
   of grazing land, resulting in a trade imbalance.
   104 108+

   In the above example relation 5.11 (21 ⟶ 99) should be scored R 11, relation 5.42 (103 ⟶ 104) should be scored R 2 1, relation 5.46 (104 ⟶ 108) should be scored R 1 2, and relation 5.62 should be scored R 1 2, because concepts 103 and 108 are incomplete.

4. Repetitions. Do not talley repeated relations even if the scoring pattern of the second occurrence of the relation is different from its first occurrence. Score only the first occurrence.

5. Identities.

   (a) When scoring a relation or implication in which one of the concepts is related to another concept by an explicit identity relation, score the relation as present and correct if either of the identity concepts is present in the subjects protocol. For example: Suppose the subject writes the following:

   "The citizens development association brought the canal
   92
   construction idea to a vote.
   119

   Since concepts 92 and 83 are identities (i.e., joined by an identity relation), you should score relation 5.60 as: R 1 1.

   (b) If both identity concepts are present and one is correct (A) and the other is incomplete (A+) or overspecified (A-), score the relation as: R 1 1

   (c) If both identity concepts are present and one is incomplete and the other is overspecified, score the relation as: R 2 1

   (d) If both identity concepts are present and both are overspecified, score the relation as: R 3 1

6. Additional Inferred or Elaborative Relations expressed as Identities. These should be marked as follows:

Type	Relation	R'	A'	B'
I	21 ⟷ S	R	1	S

Scoring Relations Involving Overspecified and Incompletely Specified Verbatim Concepts

1. Nonembedded concepts.

(a) Incompletely specified. When a nonembedded verbatim concept enters into a relation with another concept, and that verbatim concept is present in the subject's protocol but is incompletely specified, the relation is to be scored as follows:

Example: "The countries Circle Island can trade with are New Hampton and "

Score relation 5.56 as: R 1 2
Score verbatim concept "New Hampton" as correct, and score "Beatons Island" as absent (no score).

Example: "A scientist whose name is Dr. Oliver."

Score relation 5.1 as: R 1 2
Score verbatim concept "Dr. Carl Oliver" as incomplete.

(b) Substitution (overspecification). When a nonembedded verbatim concept enters into a relation with another concept and that verbatim concept is absent in a subject's protocol, but a new concept is substituted, score as follows:

Example: "The central region is called Kings Region."

Score relation 5.20 as: R 1 2
Score verbatim concept "Queensland District" as absent (no score).
List an additional elaborative concept "Kings Region".

Example: "Countries can trade with are New Hampton and Brighton"

Score relation 5.56 as: R 1 2
Score verbatim concept "New Hampton" as correct, score verbatim concept "Beatons Island" as absent, and **list** an additional elaborative concept "Brighton".

(c) Substitution and incomplete **specification**. **When a non-** embedded verbatim concept enters into a relation with another concept and that verbatim concept is present in the subject's protocol but is both incomplete and includes a substitution, score as follows:

Example: "The procanal association is called the Citizens Improvement Association."

Score relation 5.65 as: R 1 2
Score concept "Citizens Development Assoc." as incomplete, List an additional elaborative concept "(Citizens) Improvement (Assoc.)."

2. Embedded Verbatim Concepts (Enclosed in parentheses).

(a) Substitution (overspecification). When a concept has an embedded verbatim concept which is enclosed in parentheses, then that concept is to be scored independently of the verbatim concept. However, when a substitution is made for the embedded concept, that substitution must be listed as an additional elaborative concept.

Example: "Circle Island is in the middle of the Pacific Ocean."

Score relation 1.1 as: R 1 1
Score verbatim concept "Atlantic" as absent and List an additional elaborative concept "Pacific."

Example: "The senate has 12 members."

Score relation 4.10 as: R 1 1
Score verbatim concept "ten" as absent and, List an additional elaborative concept "12".

3. Embedded Verbatim Concepts (Enclosed in quotations)

(a) When a concept has an embedded verbatim concept in it and the embedded concept is enclosed in quotations, **the** subject must indicate that "something is there", but it does not matter what the words are for scoring the concept in which the verbatim item is embedded.

Example: "Circle Island is north of Roanoke"

Score relation 1.2 as: R 1 1
Score concept number 4 as correct, score verbatim concept "Ronald Island" as absent, and List "Roanoke" as an additional elaborative concept.

(b) Substitution and incomplete **specification - When an** embedded verbatim concept which is enclosed in quotations enters into a relation with another concept and that verbatim concept is present in the subject's protocol but is both substituted and incomplete, score as follows:

Example: "Farm produce is not wanted in North Hampton and Brighton".

Score Relation 5.53 as: R 1 1
Score concept 110 as correct, score verbatim concept "New Hampton" as incomplete, score verbatim concept "Beaton's Island" as absent, and list two additional elaborative concepts "brighton" and "North (Hampton)".

Scoring Relations Involving an Overspecified and Incompletely Specified Concept.

When a concept is both overspecified and incompletely specified, score as follows:

Example: "A large canal would be a barrier to flocks of seasonally migrating birds and would therefore upset the ecological balance."

Score relation 5.38 as: R 1 2
Score concept 101 as incomplete, concepts 102 and 113 as correct, and
List an additional elaborative concept "flocks of birds", to be scored: Sf 2 S
List an additional elaborative relation between 101 and "flocks of birds", to be scored: Sf 2 S
List an additional elaborative relation between "flocks of birds" and 113, to be scored: Sc S 1
List an additional elaborative implication between (101 ⟶ "flocks of birds") and 102, to be scored: Sf S 1

Trivial Transformations

A transformation should not be scored unless it changes the sense of the relation between the two concepts involved such that the relation is no longer "true" in the sense of what has been stated in the passage. For example, a subject may state that "farmers caused a procanal group to be formed" rather than "formed a procanal group" or they might write "the ten best administrators make up the senate". These transformations of mode and direction are trivial in that they do not change the "sense" as represented in the mapped relations and therefore should be scored as "R" rather than as transformations. Using this as a guide, transformations should be relatively rare.

Decisions involving implied causality.

Certain English constructions, particularly eliptical constructions and constructions involving participles and infinitives answer the question "why" and imply some cause-effect relation.

Examples:

1. Taking advantage of their power, the senators limited the size of the canal.
2. Being more prosperous, no ranchers are farmers.
3. The farmers formed a procanal group to lobby for a canal.

In the above examples, only those instances in which the cause-effect relation is inescapable are to be scored as conditional relations. Therefore, only example 2 above would be scored as a conditional relation between "being more prosperous" and "no ranchers are farmers, e.g.

ranchers → being more prosperous ⟹ ranchers → not farmers

Example 1 should be scored:

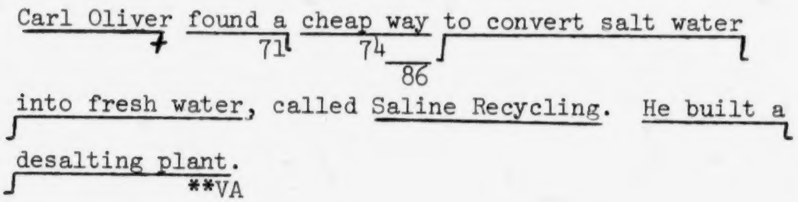
senators → taking advantage of their power
senators → limited the size of the canal

Example 3 should be scored:

farmers → formed a procanal group → to lobby for a canal

Procedures for directly marking protocols: The following marking procedures have been successful in scoring directly on the computer listed protocols:

1. Note if a concept is to be scored incomplete or over-specified, e.g. 98+ or 98-.
2. Note the section number for additional inferred and additional elaborative concepts, e.g., **III or *VA. This should be done with Roman Numerals.
3. Be sure to write in the concept numbers in the order in which they are to be sequenced, e.g.,



Carl Oliver found a cheap way to convert salt water
into fresh water, called Saline Recycling. He built a
desalting plant.

SET RELATIONS SCORING SHEET

ITEM TYPES
1. Nothing precedes explicit items.
2. An "I" precedes inferred items.
3. An "E" precedes elaborative items.

SCORE CATEGORIES
1. A', B': 1(A), 2(A+), 3(A-), or blank (0).
2. R': R, M, D, I, MD, MI, SF, SC (elaborative)

SEMANTIC RELATIONS

Type	Relation		R'	A'	B'
	1.1	2 → 3	___	___	___
	1.2	2 → 4	___	___	___
	1.3	2 → 5	___	___	___
	1.4	2 → 6	___	___	___
	1.5	6 ↔ 7	___	___	___
	1.6	2 → 8	___	___	___
	1.7	2 → 9	___	___	___
	2.1	11 → 20	___	___	___
E	2.2	12 → 127	___	___	___
I	2.3	12 → 14	___	___	S
I	2.4	12 → 15	___	___	S
I	2.6	13 → 11	___	S	___
	2.7	11 → 25	___	___	___
	2.8	21 → 22	___	___	___
I	2.10	21 → 26	___	___	S
	2.12	21 → 23	___	___	___
I	2.13	13 → 16	___	S	S
I	2.14	13 → 21	___	S	___
I	2.15	13 → 12	___	S	___
I	2.16	13 → 24	___	S	S

CONDITIONAL RELATIONS

Type	Relation		R'	A'	B'
	1.8	(2→9)⇒ (2-10)	___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
I	2.5	(21→ 22)⇒ (12→ 14)	___	S	___
	2.9	(21→ 77)⇒ (21→ 23)	___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___
	___		___	___	___

14. Summary of Possible Score Patterns

Concepts

A summary of all possible subject transformations on any explicit or inferred relation (which is either stated explicitly or is derivable from the input essay) consisting of two concepts and a connecting relation or implication is given in Figure 3.9. If A'R'B' represent any set relation stated in a subject's protocol, and ARB represents any set relation stated explicitly in the input essay (and located on the map), then any concept A' found in a subject's protocol may be a correct representation of A, an incompletely specified representation of A, or an overspecified representation of A. If the subject's concept A' does not correspond to any explicit mapped concept, it is considered to be subject-produced. If a subject-produced concept A' enters into any relations (with explicit concepts) which are necessarily true, the concept is considered to be inferred; otherwise it is considered to be elaborative. Thus, on the concept scoring sheets, explicit concepts are scored as correct (A), incomplete (A+), or overspecified (A-). Inferred or elaborative concepts (listed ones are preceded by * or **, respectively) are scored only as present (by placing a check in the A column).

Set Relations

A set relation R' in a subject's protocol corresponds to an explicit set relation R if it may be transformed into the explicit relation R appearing in the input essay (and represented in the map) by applying one of the transformations identified earlier. Every explicit set relation has been diagrammed and appears as a number (referring to the appropriate number on the map) on the scoring sheet. In the column of the score sheet labeled R' the scorer lists a code indicating precisely what transformation was required to match the explicit relation R to the subject's stated relation R'. Of course, if the explicit relation does not appear in a subject's protocol, no score is entered. For explicit relations, scores for concepts related by R' may be A (correct), A+ (incompletely specified), or A- (overspecified). Thus, there are 3 x 3 x 6 = 54 possible score patterns.

A set relation R' in a subject's protocol corresponds to an inferred set relation R if it is necessarily true. Some inferred relations and implications have been diagrammed and numbered on the scoring sheets; others have not and must be listed under "Additional Relations" or "Additional Implications". Possible scores for an inferred relation are either R or a blank. Possible scores for the concepts linked by the relation or implication R' are A, A+, A-, or S (a subject-produced inferred concept not corresponding to any mapped concept). Thus, there are 4 x 4 = 16 possible score patterns.

Elaborative set relations are relations or implications which appear in a subject's protocol and which are not explicit or inferred (i.e., they are not transformable into any explicit or inferred relation or implication). However, an elaborative relation may be false if it contradicts any relation appearing in the passage or any relation inferrable from the passage (i.e., if it contradicts the "sense" of the passage). Thus, an elaborative relation may be scored S (subject-produced but not necessarily false) or SF (subject-produced and necessarily false). Elaborative relations may involve concepts which are scorable as A, A+, A-, or S. Thus, there are 4 x 4 x 2 = 32 possible score patterns for elaborative relations.

Footnotes

Chapter 2

1. Note that these activities are not specifically identified by Rothkopf.

2. See the previous remarks concerning structured deletions and semantically incomplete texts (Chapter 1, section 1.3, page 8).

Chapter 3

1. See Chapter 9 for definitions of specific semantic relations including the "case" relations agent, instrument, object, etc.

2. See Chapter 9 for a discussion of the semantic relation "theme."

3. Negation is represented by negating a concept-set. Qualifying modals are not represented in the present model. The semantic model presented in Chapter 9 defines a set of operators on the truth value of a proposition which operate on the truth value of a relation defining a proposition.

4. See footnote 3.

5. For a complete account of the scoring procedures discussed here, see the manual for scorers which is reproduced in Appendix A.

6. As will be seen in Chapter 9, this may be due in part to the fact that it is by no means clear what constitutes a valid inference for certain propositions devised to represent natural language discourse.

Chapter 4

1. According to the model developed in Chapter 2, the semantic structure for this sentence is (simplifying somewhat):

$$\begin{array}{lllllll} & & & \text{SOURCE} & [\text{car} & \text{LOC} & \text{road}] \\ \text{John} & \text{AGT} & \text{move} & \text{OBJ} & \text{car} & \text{CAT} & \text{new} \\ & & & \text{FAC} & [\text{car} & \text{LOC} & \text{garage}] \end{array}$$

Chapter 4 (cont'd.)

2. Verification of class correspondence might be described alternatively in comparison to verification of identity as a process involving the discrimination of concept classes. Types of verification not involving an identity match might be called weak verification but the general term adopted here is verification of a derivational match since if appropriate operations are applied to generated elements, a match would result.

Chapter 5

1. It is naturally not possible to test this hypothesis exactly.

2. Note that if the experimental groups differ in total amount of semantic information acquired, these hypotheses could be interpreted in terms of the relative frequencies of the appropriate response classes.

3. See footnote 2.

Chapter 9

1. See, e.g., Leech's (1969, 31-34) discussion of rules of expression.

2. See Simmons (1971, 24-38) for a discussion of lexical structures.

3. See Leech (1969, 71-79) for a discussion of rules for synonymy.

4. Crothers (1970) presents a discussion of dominance.

5. This interpretation of differentiation has been adopted by Dawes (1966), Frase (1969), and Frederiksen (1971 and the present report).

6. See Crothers (1970) for a discussion of the possible importance of superordinate structures.

7. See Leech's (1969) discussion of downgrading and rank shifting.

8. Fillmore uses this example to demonstrate that an intervening "instrument" in a causal chain involving more than three objects, may not be expressed using the preposition "with" which is dominated by the case category instrumentality.

9. The latter example was offered by Fillmore, 1971, p. 41.

10. A series of papers by Zadeh (1964, 1968, 1971a, b) are concerned with the problem of representing imprecise statements in set notation as "fuzzy sets" and with exploring properties and applications of

Chapter 9 (cont'd.)

this definition. A fuzzy set is defined in terms of a "membership function": assigning to each object x in a space of objects X a real number $f(x)$ $(o < f(x) < 1)$ which represents the degree of membership of the object in the fuzzy set.

11. See Leech's (1969, pp. 232-238) discussion of the "hypothetical formator."

Chapter 10

1. If a model is to be fit to data based on a single instance of a graph-structure (e.g. the above example), a model is required which relates a linear structural model to a binary response vector $\underline{v}$.

2. Jöreskog, K. G. and van Thillo, M. LISREL-- A general computer program for estimating linear structural relationships. Research Bulletin, Princeton, N.J.: Educational Testing Service, 1973.